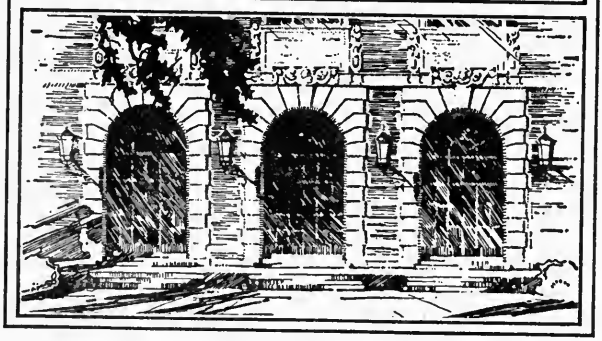
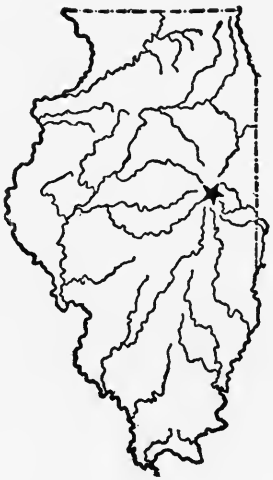


Agricultural Experiment Station
UNIVERSITY OF ILLINOIS

BULLETIN No. 275

APPLE BREEDING AT THE UNIVERSITY OF ILLINOIS

By Charles S. Crandall



URBANA, ILLINOIS, JUNE, 1926

FOREWORD

Apple breeding now in progress at the Illinois Agricultural Experiment Station was instituted in 1907. In that year projects were outlined, schedules of procedure were adopted, and the collection of breeding material was begun. The projects proposed were outlined under five divisions as follows:

1. Bud selection: an attempt to determine whether or not permanent improvement in varieties of apples can be effected thru propagation from selected buds.

2. Growing seedlings from exceptional trees: an attempt to determine whether or not improvement in varieties of apples can be effected by growing seedlings from trees that have attracted attention by reason of productiveness and exceptional character of fruit.

3. Hybridizing reciprocally between standard varieties of apples and such other species and varieties of the genus Malus, both foreign and domestic, as can be brought to flowering.

4. Hybridizing standard orchard varieties with a view to securing combinations of the most desirable characters of both parents.

5. Crossing different strains of the same variety or selected individuals of the same strain.

Divisions 1 and 2 were considered in Bulletin 211, "Apple-Bud Selection; Apple Seedlings from Selected Trees," issued in 1918. The purpose of the present publication is to consider divisions 3, 4, and 5, not for the purpose of presenting results, for results are only just beginning to accrue, but to bring together, in form for convenient reference, the data accumulated up to and including 1924, to describe and discuss the various species and varieties that have been used as parents, to give in some detail the methods used in performing the various operations, and to record the present status of more than 20,000 seedling trees that have been grown from the seeds of hybridized fruits.

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APPLE BREEDING AT THE UNIVERSITY OF ILLINOIS

By Charles S. Crandall, Chief in Plant Breeding in Horticulture

INTRODUCTION

At the beginning or very early in the development of any contemplated plan of apple breeding, the breeder is sure to be confronted by certain discouraging features. There is first the interval between generations; the certainty that a long period of patient waiting must precede attainment of any results whatever touching the method of transmission of fruit characters. There is also the probability that when first generation hybrids are brought to fruiting, at the end of nearly or quite a full decade, it will appear that only the first of several equally long but necessary steps has been taken towards a satisfactory understanding of the principles involved in the descent of specific characters.

A further difficulty, growing out of the recognized confusion in nomenclature that prevails within the genus, is that of establishing, in any satisfactory way, the systematic positions of the various forms that it is proposed to hybridize. Still another source of discouragement is that encountered in attempting to describe the numerous forms in such manner that the differentials will serve the purpose of definitely distinguishing one form from another; inconstancy is an attribute of many of the characters commonly employed to differentiate species and varieties. Most of the characters thus far studied exhibit such extremes of variation as to bring them in question as elements of a substantial basis upon which separation of forms may safely rest.

It is the misfortune of the apple breeder that the material with which he works is mongrel. The commonly available varieties of the orchard have been perpetuated by asexual propagation for long periods; historical data regarding time, place, and manner of origin are wanting, and nothing whatever is known regarding remote or even immediate ancestors. This same condition applies to all introduced crab-like forms; grown for indefinite periods in association with other forms, passed thru an unknown number of seminal generations, they have come as ornamentals, most of them bearing evidences of hybridization, but unaccompanied by historical facts and their origin wholly a matter of conjecture.

Since nothing is known of the gametic composition of the apple forms available for breeding, and nothing of the potency, constancy,

or heritable qualities of characters possessed by individuals, there is no tangible basis from which the results of any particular cross can be predicted. The attempt to combine, in the progeny, two desirable qualities, one possessed by each of the two individuals mated, is as likely to result in the entire elimination of one or both of the qualities, so far as their presence is apparent to the senses, as in the unimpaired retention of either or both, in sensible form, in a single individual. The qualities in question appeared, each in a single individual, at some remote period; they have been maintained by vegetative propagation and there is no way of judging how they will behave when combined in company with numerous other characters any of which may, in meeting its proper mate, assume ascendancy over the chosen characters.

How, then, are forms for mating to be chosen? The writer has no answer to this question other than to express the opinion that in the absence of knowledge of the qualities of particular characters no intelligent selection of parents can be made. A first essential is to learn by actual matings how the various characters of parents appear, or fail to appear, in the progeny. Are they transmitted intact, do they appear in modified forms, or are they entirely suppressed? Facts that will assist in answering these questions are confidently expected from the numerous hybrid progeny now growing in the orchards. These seedlings represent numerous combinations, many of which were made with specific objects in view, some from motives of convenience, and some as purely random matings. Naturally great interest centers in these hybrid seedlings, because if they do not throw such light upon the nature of the characters of the various forms as will serve to guide future matings, then will the labor have been in vain.

PROCEDURE FOLLOWED IN POLLINATING WORK

Spring Weather and Flowering

Pollination of flowers of apple varieties in the orchard is attended with many uncertainties because of unfavorable weather conditions at blooming time. These conditions vary greatly in different seasons and may affect the work of pollination by departures from normal in either direction. In some seasons the flowering season is extended over about two weeks, or even a little more; this means rain, low temperatures, high winds, and conditions generally unfavorable to flower development and to success in pollination.

Sometimes there are frosts, but cold rains and high winds, even in the absence of frost, may so impair the vitality of floral organs that the most careful applications of pollen to stigmas fail to result in fruits. When such conditions prevail, flowers do not open normally, filaments do not elongate, styles remain short with stigmas clustered

in the center of the flower; and the manual operations of emasculation and pollination are performed with difficulty and discomfort, and discouragement is the net result.

On the other hand, a hot wave with accompanying bright sun and balmy breeze will push buds with such rapidity that all flowers open nearly at the same time; thus the flowering period is so shortened that, even with all preliminaries arranged to expedite procedure, pollinations fall far short of what it was hoped and expected would be accomplished. If the hot wave comes sufficiently late and is not followed by killing frosts, crops are produced, pollinations are reasonably successful, and the breeder regrets only the limited amount of work performed. But if the heat that unduly stimulates comes early, the probability of disaster from bad storms amounts to almost a certainty.

The date of full bloom for Oldenburg in this locality, as averaged from the records of twenty years, is May 2. In 1910 the first flower opened April 3 and full bloom was recorded for April 8. A storm April 23-25, during which there was rain, snow, high wind, and freezing temperatures, completely ruined the prospective crop. For the twenty years for which the average date of full bloom was computed, two years—1902 and 1912—had the average date, full bloom fell on later dates in eight years and on earlier dates in ten years. The years of full crops were included in the eight years of late bloom, but even here some injury from frost was inflicted in two of the seasons. The lean years were the years of early bloom, for in each of the ten years there was more or less serious injury from bad weather. Only in the years 1910 and 1919 was the destruction complete.

LENGTH OF BLOOMING PERIOD

The length of blooming period is extremely variable, with the extremes far apart. The full period was ten days in 1901 and 1915, and twenty-two days in 1907. The average of all years is sixteen days. Blooming periods for individual varieties vary widely and with great irregularity. A variety having a four-day period in one season may have the period lengthened in another year to as much as sixteen days. Two varieties, one having a blooming period three times as long as the other in any one year, may exactly reverse this relation in a following year. No variety is constant in length of blooming period, but some varieties vary more widely than others. Causes for the irregularities observed are difficult to determine, in any definite way, because the factors involved are too numerous and varied. Of course weather conditions are important, but the condition of the individual is equally important and is dependent upon conditions to which it has been subjected thru preceding months or years; qualities are developed that render it more susceptible to stimulation or less resistant to adverse conditions in one season than in another.

This phase of the subject has been treated in some detail in Bulletin 251, "Blooming Periods of Apples," issued in May, 1924.

LENGTH OF THE PERIOD OF POLLINATION WORK

The number of days over which the field work of emasculation and pollination extends varies in different seasons according to the weather, and has ranged, for the last fifteen years (1909 to 1923) from three to twenty-two days for emasculation, and from three to eighteen days for pollinations, or the full period from the first emasculation to the last pollination has varied from five days in 1920 to

TABLE 1.—LENGTH OF POLLINATION PERIOD FOR EACH OF THE YEARS 1909 TO 1923

Year	Emasculations			Pollinations			Full period of work, days
	Begun	Ended	Days	Begun	Ended	Days	
1909....	May 1	May 7	7	May 4	May 10	7	10
1910....	Apr. 4	Apr. 14	11	Apr. 7	Apr. 20	14	17
1911....	May 1	May 10	10	May 4	May 12	9	12
1912....	May 1	May 6	6	May 6	May 8	3	8
1913....	Apr. 29	May 6	8	May 3	May 7	5	9
1914	Apr. 29	May 4	6	May 1	May 5	5	7
1915....	Apr. 23	Apr. 27	5	Apr. 27	Apr. 29	3	7
1916....	Apr. 28	May 9	12	May 2	May 11	10	14
1917....	Apr. 25	May 16	22	May 1	May 18	18	24
1918....	Apr. 27	May 8	12	Apr. 30	May 9	10	13
1919....	Apr. 22	Apr. 22	..	.....	.....	..	..
1920....	May 11	May 13	3	May 13	May 15	3	5
1921....	Apr. 21	Apr. 26	6	Apr. 23	Apr. 28	6	8
1922....	Apr. 21	May 2	12	Apr. 24	May 3	10	13
1923....	May 2	May 12	11	May 5	May 14	10	13

twenty-four days in 1917. Records of the actual days of pollination work for the fifteen years appear in Table 1.

In 1910 the storm that brought temperatures low enough to kill all fruits did not begin until three days after the last pollinations were made. In 1919 there was no protracted storm, as in 1910, but temperatures went low enough, on the morning of April 23 and again on April 24, to kill blossoms and stop emasculating, which had been begun on April 22.

The longest full period was that of 1917, April 25 to May 18, twenty-four days; ordinarily a flowering period thus extended would mean storms and dangerously low temperatures, but, in this instance, there were no severe storms and blossoms were not subjected to injury from frost. There prevailed a period of reasonably pleasant weather with temperatures low enough to retard flower development. Hot waves, such as occurred in 1912 and 1915, which brought flowers forward so rapidly that the days of pollinations were reduced to three, were absent in 1917. Conditions in this year approximated the

breeder's ideal; there were no storms to cause injury, nor heat waves to unduly crowd the work.

Practice at this Station has been to separate the operations of emasculation and pollination. A schedule of the desired crosses is prepared in advance and emasculation begins as soon as buds are sufficiently developed. The entire force engages in emasculation for one, two, or three days, depending upon the amount of work and the rate at which buds are advancing toward anthesis; then there is a division: several workers continue emasculating while others begin pollination, taking first the earliest emasculations. Toward the end of the campaign all workers assist in completing the pollination of flowers that have been emasculated; the aim is to come out even and as near the limit of time for possible pollinations as may be. Sometimes, when the end is in sight and it is discovered that certain late flowering varieties still have workable buds, additional emasculations are made, but with these, pollination is performed at the time of emasculation.

Some breeders advocate pollination at the time of emasculation as the most satisfactory practice, and there are a number of points in favor of such practice, particularly in that it completes the work at one operation; but having given both methods a somewhat extended trial, the opinion is retained that for the climatic and labor conditions under which the work is done at this Station the method of deferred pollination is decidedly the more satisfactory. One of the points in favor of this procedure lies in the fact that there is opportunity to check the character of the work done in emasculating, and where student or other unskilled labor is sometimes employed this is important. Upon the removal of the bags, at the time of pollinating, flowers are not infrequently found that were incompletely emasculated or that had been injured by some slip of the tool used in emasculating; such flowers may then be discarded, because if allowed to remain they serve no purpose except to increase the error in computation of success percentages.

There is, of course, a very definite limit to the length of time application of pollen can be deferred; this limit depends chiefly upon temperature and upon the degree of advancement of the buds at time of emasculation. If temperatures abnormally high for the season are prevailing, the interval must be shortened to one or, at most, two days; if temperatures are so low that development of floral organs is slow, the interval may extend to four or five days. It is essential that pollen be applied before there is any evidence of browning of the styles, and, on the other hand, it should not be applied until exudation of the stigmatic secretion indicates a receptive condition. It is only necessary to observe carefully the rate of development and govern

APPLES: Pollination Record Spring of 1916

Female Parent Oldenburg (Late) Male Parent 833 M. Malus fl. pl.

Location Sook Forty Row 1 Tree 31 Location Sook Forty 4th middle Row 1 Tree 31

Emas. by H.R.A. Date 5/3 Hour 4 p.m. Poll. by H.R.A. Date 5/5 Hour 3 p.m.

Date pollen taken 5/1 Hour 8 a.m. Age of pollen (in hours) 103

Serial Number	No. fls. in cluster	No. fls. Emas.	No. fls. Poll.	Fruits set 5/30	Fruits set 7/26	No. fruits picked	Date picked and described
10601	6	2	2	1	1	1	Aug. 5. 1916
10602	5	2	2	1	1	1	Aug 8. 1916
10603	5	2	2	2	1	1	Aug. 8. 1916
10604	6	2	1	1	1	1	Aug. 8. 1916
10605	4	2	2	1	1	1	Aug. 5. 1916
10606	6	2	2	0			
10607	4	2	2	1	0		
10608	5	2	2	1	1	1	Aug. 8. 1916
10609	4	2	2	1	1	1	Aug. 8. 1916
10610	6	2	2	2	1	1	Aug. 8. 1916
10611	5	2	2	1	1	1	Aug 8. 1916
10612	4	2	2	2	2	0	Sack split and fruits lost
10613	4	2	2	2	1	1	Picked Aug 5 1916 Destroyed Aug 7. 1916
10614	5	2	2	2	2	2	Aug. 8. 1916
10615	5	2	2	2	2	2	Aug. 8. 1916
10616	5	2	2	0			
10617	5	2	2	1	1	1	Aug. 8. 1916
10618	4	2	2	1	1	1	Aug. 8. 1916
10619	5	2	2	1	1	1	Aug. 8. 1916
10620	5	2	2	1	1	1	Aug. 8. 1916
10621	6	2	2	2	2	2	Aug. 8. 1916
10622	5	2	2	2	2	2	Aug. 8. 1916
10623	6	2	2	1	1	1	Aug. 8. 1916
10624	5	2	2	2	2	2	Aug 8. 1916
10625	6	2	2	1	1	1	Aug. 8. 1916
			49	32	28	26	

FIG. 1.—POLLINATION SHEET; REPRODUCTION OF AN ACTUAL RECORD

Records were kept on loose sheets of heavy paper measuring 8½ by 11 inches. When the record was filled, the sheets were inserted in ring-binders for permanent reference.

action by these observations in order to make the applications at the time when the condition of the stigmas is at its best.

RECORDING EMASCULATIONS AND POLLINATIONS

Reference has been made to pollinations, and some explanation should be given of the method adopted for recording and labelling. Records are kept on what are known as "pollination sheets" (Fig. 1); these are letter-size sheets of heavy paper, which, when filled, are bound for easy reference in "ring-binders."

At the time of emasculation, the name and location of the tree are entered, and the two columns, number of buds to the cluster and number emasculated, are filled. The rule with orchard varieties is to emasculate two buds in each cluster used; the others are removed. It is preferred that only one of the two emasculated buds in each cluster develop as fruit and certainly no more than two fruits are desirable for any one cluster. With crab-like forms that commonly bear the fruits in clusters of from three to six, all buds, except abnormally small ones, are emasculated, and frequently several clusters are bagged under one number.

At the time of pollination, the name and location of the pollen parent, day and hour of pollination, and age of pollen are entered, and the column "Number of flowers pollinated" is filled. In use, the sheet is held to a backing of binder's-board by rubber bands and may lie on the broad top of the step-ladder, or may be hung from a twig, as seems most convenient.

METHODS OF EMASCULATING APPLE BUDS

The aim in emasculating is to remove all of the anthers before the commencement of dehiscence and without injury to the pistil; this can be accomplished most readily when buds are on the point of opening, because then the filaments have become elongated and the anthers are not so closely associated with the pistil as in less developed buds. However, when a large number of emasculations is contemplated, it is manifestly impossible to have all buds in this ideal condition. Usually there are differences in the degree of development of the buds of a cluster and those nearest the desired development may be selected; at the beginning of the season the larger are chosen, near the end the smaller, because the larger are partly or fully open and must be discarded.

There are two methods of emasculating apple buds, each of which has its advocates. The petals may be forced aside or cut off and the anthers picked out with tweezers, or cut out with scalpel or scissors; by this method there is no mutilation of remaining parts except the petals. By the other method the calyx cup is cut thru, just below insertion of the stamens, thus removing all floral organs except the pistil. With the peach this last method is much the easiest, most expeditious, and is practiced without danger to the pistil, because the

ovary is free and the calyx cup is relatively broad. In the apple bud the calyx is adnate to the ovary, the calyx cup is contracted and insertion of stamens brought into such close proximity to the pistil that extreme care is necessary in guiding the cutting tool to effect the purpose without injury to the central organ. A minor objection to this method is that such fruits as develop are more or less deformed by removal of the calyx. Both methods have been used, but emasculation without unnecessary mutilation is regarded as the better.

PROTECTING EMASCULATED BUDS

Nothing has been found that serves the purpose of protecting emasculated buds so well as size No. 1 paper bags. Care is necessary in choosing the brand, for all bags are not equal in the essentials—lightness, toughness, and resistance to rain. Protracted rain accompanied or followed by high wind will sometimes destroy the best bags made by constant whipping about, but little loss has been experienced from this cause. In adjusting the bags, care should be taken to expand the satchel bottoms to the fullest extent so that they may stand away from the buds. Bags are tied on with cotton cord cut to proper lengths and carried in such manner as to be ready at hand as wanted; the length should admit tying in a single bowknot so that untying is easy when the time comes to remove for pollinating.

In choosing clusters the flowers of which are to be emasculated, the matter of position is worthy of attention. The ease with which the subsequent operations of tying the sack and of pollinating are performed will depend upon the choice of clusters, and usually bloom is so abundant that only such clusters as are conveniently situated need be taken. Terminal clusters of very short spurs from large branches are not considered desirable because they are difficult to cover, and terminal clusters of long, willowy shoots are liable to injury from whipping about by wind.

METHOD OF LABELLING CLUSTERS

As soon as the two flowers of a chosen cluster are emasculated, the record of that cluster is entered on the sheet opposite one of the serial numbers; then a label bearing a corresponding number is attached close enough to the cluster to be identified as belonging to it. This label establishes a permanent relation between the cluster and the written record of the cluster; it must be securely attached and must remain readily legible thru five or six months' exposure to sun, wind, and rain.

The labels are prepared in advance. They are strung on wire hooks in lots of twenty-five, the labels on each hook corresponding to the serial numbers of a particular sheet, while the numbers they bear are in the same sequence as the serial numbers on the sheet. The

label used with entire satisfaction for several years is the standard string tag No. 542 made by the Dennison Company. This gives a writing surface 7/8 inch square, sufficient for the number, which is all that need be placed on the label. The number is put on with a brush, using a paint consisting of shellac, cut in alcohol, to which is added sufficient lamp-black to give color; this paint dries immediately and the numbers remain legible far beyond the necessary limit. Fig. 2 shows three of these labels as they appeared after hanging on the trees for 292 days. The labels are quickly attached by simply looping the cord about the twig.

FIG. 2.—LABELS USED ON TREES TO IDENTIFY CLUSTERS

When these labels were photographed they had hung on trees in the orchard for 292 days—from April 14, 1910, to January 31, 1911.

COLLECTING AND PRESERVING POLLEN

Providing a sufficient supply of pollen for use as wanted is one of the important requirements of the pollinating season. It is most readily obtained from flowers just opening or from buds nearly ready to open. The usual procedure is to select small branches on which a considerable portion of the buds are nearly ready to open, take them to the laboratory, and there remove the anthers. If temperatures have been low and the rate of bud development slow, the branches may be placed in water in the greenhouse for two or three days to allow further development of anthers, but if high temperatures have prevailed and all conditions have been favorable to the rapid maturity of buds, it is not unusual to extract the anthers immediately after collecting the branches. It is essential that the anthers be mature and as near dehiscence as possible.

Under the conditions that prevail in some seasons, orchard trees burst into full bloom very suddenly; on one day there may be here and there an open flower, while on the following day practically all flowers are open. If an early morning examination promises opening of the mass of flowers on that day, branches of flowers should then be gathered from which to extract pollen. By discarding such flowers as may be fully open and such retarded buds as may be found, reasonable uniformity in the development of the anthers removed may be secured.

Anthers may be removed either with tweezers or with the fingers. This is a matter of personal preference on the part of those doing the work, but after thoro trial of both methods it is believed that anthers

can be more rapidly extracted with the fingers than with any tool yet devised. The anthers as extracted fall into a Petri dish 10 cm. in diameter, or, for small quantities from trees supplying only a few clusters of buds, into dishes of half that diameter. When anthers have been collected in considerable quantity, the dishes are removed to some dry place, protected from currents of air, and allowed to remain until the anthers have opened; this requires from twenty-four to forty-eight hours depending upon the temperature and, largely, upon the humidity of the air.

Each dish is labelled, in advance of use, with a gummed label placed within the dish on the bottom; on this label is recorded the name or number of the variety, the location of the tree, and the day and hour of collection. Altho the label might be read more easily if placed on the cover, the arrangement invites error thru possible exchange of covers when a number of similar dishes are in use. When a large quantity of pollen of one variety is desired it is better to use two or three dishes than to place the entire amount in one, both because the small content of the dish dries out more quickly and the anthers dehisce better, and because the additional dishes insure against loss of all the pollen thru accidental over-turning of the one dish. After the anthers have dehisced, covers are placed on the dishes.

Not only are there marked differences between species and varieties of Malus in abundance of pollen produced, but there are wide differences in quality and also in behavior of the pollen after dehiscence of anthers. In some varieties, the pollen, even when produced in abundant quantity, persistently adheres to the anthers; in others, it falls readily. In some the grains fall in masses which persist until broken up mechanically, in others the grains do not adhere to each other but fall singly, giving to the mass a powdery appearance. Winesap pollen is commonly deficient in quantity, often with a high percentage of imperfect grains, and usually it adheres persistently to the anthers after dehiscence. With Jonathan, Oldenburg, and Yellow Transparent, the pollen is abundant, separates readily from the anthers, falls as a fine powder, and usually contains but few imperfect grains. *Malus arnoldiana* and *Malus sylvestris fastigiata bifera* produce abundant pollen which falls readily from the anthers; with *Malus ringo* the pollen is equally abundant but adheres very persistently to the anthers. *Malus malus* var. (19667) produces only a small quantity, which remains adherent to the anthers. Stayman Winesap has very plump anthers, and pollen is abundant and strongly adherent; when this pollen falls or is forcibly brushed from the anthers it remains indefinitely in small masses which retain the orange color of fresh pollen.

Adherence of pollen grains to each other or to the anther sack is not an index of viability. In ability to fertilize, the most persistently

adherent pollen appears equal to that which falls as powder, but the latter type is more easily distributed on stigmas and is preferred for use in pollination.

Pollen collected as described above is kept in the Petri dishes and used direct from these dishes as long as there are flowers to be pollinated. The only precautions taken are to protect the pollen from exposure to the air, and to store the dishes in a dry place at night.

DESCRIPTION OF APPLE POLLEN

Normal grains of apple pollen, in the dry state as taken from anthers, are elliptical, or oval, in form, the long axis usually about one and three-fourths times the length of the transverse axis; the surface is smooth, usually with a single longitudinal fold extending from half the length to full length of the grain in some cases. Each normal grain has three pores, or thin places, in the outer coat (extine); these are situated at equal intervals at the circumference midway of the long axis.

Because of the densely granular content of the grain, these thin places are not readily seen in the dry grain, but by careful adjustment in relation to light the pores can be brought into view one at a time, when they appear as small translucent spots sometimes protruding slightly beyond the surface. On application of water, the grains immediately swell and become almost spherical; even with pollen that has been stored for months, enlargement takes place promptly altho full size is not so quickly attained as in the case of fresh pollen.

In swelling, the short axis elongates until it approximates the long axis in length. The long axis usually remains much as in the dry grain, but may vary in some degree, at times elongating slightly and again becoming slightly shorter. When grains are wet, the pores or thin places in the outer coat become very distinct and often appear as knob-like protrusions; they give to the grain a triangular appearance when viewed from the end; the grains, however, are almost perfectly spherical, as is readily demonstrated by rolling them under a cover glass. Treated with concentrated sulfuric acid, the thin places in the outer coat as well as the inner coat and the granular contents are disintegrated; the outer coat curves outward at the margins of the openings and the walls appear divided into triangular segments.

In germination the inner coat protrudes from these pores in starting the growth of the pollen tube. The three pores suggest the possibility of three pollen tubes, but usually there is only one. In only one case has indication of a second tube been seen, and then while one tube elongated normally the other remained short, attaining a length but little exceeding the diameter of the grain. In all lots of pollen examined dry, as taken from the anthers, there appeared mingled with the normal plump grains, a varying number of grains that were spheri-

cal and of small size, others of irregular and some of rectangular form; these are imperfectly formed grains which are incapable of functioning and never emit tubes. When brought into contact with water or when placed in saccharine solutions, some of these imperfect grains promptly burst and discharge their contents; others neither burst nor in any way change form, but remain intact indefinitely. The relative abundance of these defective grains serves, in a general way, as an index to the probable value of the pollen for use in crossing.

Pollen grains from different species and varieties of Malus exhibit some slight differences in size, but there are as great, or in some instances greater, differences between grains from different individuals of the same group as there are between different groups. Size, as well as the relative proportion of inferior grains, appears to depend almost wholly upon the health and vigor of the individual plant. Measurements have been made of the pollen of twenty species and varieties of Malus and of five orchard varieties; the measurements recorded are the averages of the measurements of ten grains, dry and again after application of water. The largest grains are those of *Malus coronaria*, which measure 32 x 46 microns when dry, and 48 x 53 microns when wet. The smallest grains are those of *Malus baccata*, measuring 19 x 35 microns dry, and 34 x 35 microns when wet. For the twenty species and varieties of Malus the average is 23 x 40 microns dry, and 36 x 40 microns wet. The averages for the five orchard varieties are 25 x 43 microns dry, and 38 x 42 microns wet.

Application of Pollen to Stigmas

Buds having been emasculated and stigmas developed to a fully receptive stage, the next procedure is to apply pollen. This may be done in various ways: some breeders use a camel's hair brush, others recommend use of the fingers; the handle of a pair of tweezers may be used, or any other piece of polished metal of proper form, or anthers on the point of dehiscence may be brushed over the stigmas. There is no more effective method than that last mentioned, but it is impracticable for any but small undertakings, because, if the pollen is properly guarded against contamination the work cannot be done with the rapidity desired in large operations.

Various methods have been used in work at this Station, but the one most in favor, because both effective and expeditious, is that of providing the pollen, in ample quantity where possible, in Petri dishes 5 cm. in diameter, and thrusting the stigmas directly into the pollen mass wherever they can be brought into such position as to admit this procedure. If flowers stand erect on spurs too rigid to be deflected, the smooth handle of tweezers is used to transfer the pollen from the dish to the stigmas; pollen adheres readily to this tool and is easily scraped off by the stigmas. When finished with one kind of

pollen, the tweezers are quickly sterilized by immersion in a vial of alcohol and at once are ready to use with another kind of pollen without danger of contamination.

FIG. 3.—CHEESECLOTH BAGS PROTECTING APPLE CROSSES ON A ROE'S DUCHESS TREE

These cheescloth bags replace the paper bags after it is determined that fruit is developing, and are left on until the fruit is mature. This photograph was taken in August, when the fruit was nearly mature.

The chief points in pollinating are to cover the stigmas thoroly with pollen, to use only well-developed pollen that has been thoroly dried, to minimize as far as possible the danger of admitting undesired pollen, to exercise care not to bend or break styles, pedicels, or spurs, and to see that the bags when readjusted are securely tied.

Pollination completed, the bags remain undisturbed until it is convenient to make an examination and ascertain the apparent success. Usually this examination is deferred for four or five weeks, or until it is thought probable that fruits that started without having been fertilized may have fallen, or have assumed the yellow color indicating an early fall. The only objection to delayed examination that has thus far appeared is that green aphis may establish colonies within the sacks and destroy or injure the young fruits; presence of these insects can be determined only by removal of the sack. Since cases of such invasion have not been common and the labor of examination is considerable, the deferred examination will be continued, for a better index of the probable number of fruits that will mature is obtained then than would be possible earlier. At the time of this examination the paper bags are removed, record is made of failure or apparent success, and in all cases where fruits are developing a cheesecloth bag replaces the paper bag to remain until the fruit is picked. These cloth bags serve as a protection to the fruit and are not in danger of being missed when harvesting. Protected fruits nearing maturity on the tree are shown in Fig. 3 from a photograph taken in August.

SOME GENERAL CONSIDERATIONS REGARDING RESULTS OF POLLINATIONS

Flowers are emasculated, pollen applied to stigmas, and every detail in the process carefully and thoughtfully executed. What will

be the result? Presumably, in each case pollen tubes will grow, descend the styles to the nucleus within the ovary, fertilization occur, and the ovary develop into a fruit containing seeds from which will come the next generation. If this sequence of events were universal, and viable seeds resulted from each transfer of pollen, the labor of the plant-breeder would be much simplified. But results are frequently disappointing; laborious preparation of flowers and the utmost care in succeeding operations are often attended with complete failure, or a very unsatisfactory percentage of success.

Where success does not attend efforts to hybridize, questions regarding reasons for failure naturally arise. The problems presented cover the full range of plant activities; they are complex and do not admit ready and satisfactory solution. Attempts to analyze the circumstances and conditions under which the work was done find uncertainties enveloping many important points, chiefly because results are not immediate; weeks or months may have elapsed since the initial operations were performed, and memory is at fault regarding distant details. It is remembered that the plants, to all appearances, were vigorous, that flowers opened normally, stigmas were properly developed, pollen was viable, and weather conditions favorable. Nothing unfavorable to the formation of fruit and seeds can be recalled. Here enters the temptation to dismiss the matter with an assumption and conclude that failure resulted from want of affinity between the plants paired. When crossing is attempted between remotely related plants, as between varieties of unlike species, failure is common; it is expected and appeal to want of affinity as a cause is, perhaps, justified. But in apple breeding most of the combinations attempted are between forms that are much alike. The disappointment comes when these similar forms, presumably closely affiliated botanically, refuse to respond to efforts to cross them. This they frequently do and satisfactory reasons for the failures are difficult to assign. To say that failure to produce fruit is due to want of affinity between the plants may be true, but there is no proof that this is the cause of failure; as commonly used, the expression "want of affinity" simply serves as a convenient cover for ignorance of the true reason for failure.

Repeated trial of the same cross, always with the same result, will finally afford a basis upon which the assumption of want of affinity may rest, and the safety in which it rests is in proportion to the number of tests upon which the assumption is based.

In some cases a plant is fruitful when the stigmas are supplied with one kind of pollen and infertile when other kinds are used; it is said of such a plant that it has affinity for the accepted pollen and antipathy for that refused, or that it has a certain selective power.

Here again only repeated occurrence of the same phenomenon gives warrant for the conclusion that the plant is habitually sterile with one kind of pollen and fertile with another.

There are seasonal differences in plants, differences in general vigor that react, in conjunction with atmospheric or other surrounding conditions prevailing at the time pollination is performed, in a way that may affect the result one way or the other. This may be illustrated by reference to an experience with an attempted cross between two varieties. Domine pollen, used on 57 flowers of Winter Rambo in 1909, gave no fruits; 47 flowers on the same tree of Winter Rambo pollinated in 1911 with pollen from the same tree that supplied pollen in 1909, gave no fruits,—complete failure in two seasons. The suspicion seemed warranted that here was a case of habitual refusal on the part of Winter Rambo to accept Domine pollen, but in 1913 mating the same individuals in the same way gave 7 fruits with perfect seeds from 47 pollinations. No better conditions prevailed at flowering time in 1913 than in the years when complete failure resulted; there were no evidences of differences in vigor of the trees, and the manual operations in the different years were performed with equal care. The percentage of successful pollinations in 1913 was small, but sufficient to show that the suspicion of habitual sterility as applied to this cross was not well founded and that causes for the earlier failures rested on some other factor or factors not determined.

In breeding practice it is not uncommon to encounter marked differences between individuals of the same variety or of the same strain, and for this reason the behavior of a single individual for a single season does not afford secure foundation for a definite assertion regarding the fertility or sterility of the variety or strain when used in any particular combination. Failures are not confined to those combinations undertaken with expectancy of failure; they as frequently occur where success was confidently expected, and any study into causes soon brings the conviction that the factors which, singly or in combination, influence the results of pollination, are many and various. In some cases adverse results are readily and confidently ascribed to a definite cause, as when frost at time of pollination blackens styles; here is something tangible and easily detected by observation. In other cases there is difficulty, often amounting to impossibility, in isolating the active factor among several, any one of which may have been directly responsible for the observed results. In still other cases nothing is discoverable in ancestry, relationship, environment, atmospheric conditions, structure, or appearance that affords tangible support for any theory of causes that may be conceived. Plants sometimes exhibit a coyness or perversity that is unaccountable and exasperating.

SOME OF THE CAUSES OF FAILURES OF POLLINATIONS

The causes of failures of pollination are so numerous that to assign failure definitely to one of them is practically impossible. Some of these causes are open, easily observed, and their connection with particular failures may be confidently asserted; others are obscure, not readily separable as units, often operating with others, and their relation to results is more frequently assumed than definitely known.

Botanical Relationship.—Failure is the rule when crossing is attempted between plants not closely related botanically; there are exceptions, but in a broad way the rule applies. The Malus forms in the collection represent several well-defined species, a number of undoubted hybrids, and considerable range of varieties, but uncertainties attach to the relationship of most of them—uncertainties which, in the absence of historical data, can never be eliminated unless light is thrown upon them thru systematic breeding. The forms are various; they differ in habit of growth, in foliage, flower, and fruit, and yet most of them hybridize readily among themselves and with orchard varieties.

The extremes of form may be represented, perhaps, by the dwarf, spreading form of *Malus toringo* (19664), a plant low in stature, with lobed leaves and fruits no larger than peas, on the one hand, and Grimes or other orchard varieties on the other. From appearance of plants and their fruits, the collection offers no more violent cross than that between this dwarf Malus and any one of several varieties of the common apple. But these matings have been fairly successful in fruit-production; thus 29 flowers of *toringo* pollinated by Grimes yielded 18 fruits, or 62 percent of the pollinations successful; 16 flowers pollinated by Winter Rambo yielded 15 fruits, a success percentage of 93.75; 158 flowers pollinated by Oldenburg yielded 32 fruits, a percentage of 20.25; 29 flowers pollinated by Stayman Winesap yielded no fruits. The latter was the only one of eight varieties used as pollen parents that failed, and the lowest percentage attained by the other seven is that given for Oldenburg. The behavior of these plants points to a nearer botanical relationship than is indicated by the appearance of the plants or of their fruits.

Want of Affinity.—If two plants cross readily it is said that they have affinity for each other; if, of two similar plants, one refuses to be fertilized by pollen from the other, the phenomenon is referred to as the expression of an antipathy of the one plant against the other. In the first case the habitual success of pollination is evidence that the two plants accord in structure and function, and the term affinity expresses the relation. In the second case there is the evidence of failure that in some undiscovered particular the two plants are not in

accord; usually the reason for failure is not determined and it is convenient to say that there is antipathy between the plants.

It is believed that in each case of habitual refusal to cross there is a definite reason for the failure, and it seems probable that examination, in detail, of floral organs, and close inquiry into all circumstances attending pollination would lead to discovery of facts that would admit less indefinite assignment of the causes of refusal to cross than to assume that it rests in an antipathy. Such inquiries are important; they are in the nature of special problems that can be undertaken only when assigned singly to capable men who can be given all the time and equipment necessary to carry the problems to successful conclusions.

Impaired Vigor of One or Both Parent Plants.—Reference is made here to such possible impairment of vigor as may result from starvation, drouth, excessive moisture, or other adverse conditions to which the plants may have been subjected during the period of bud formation. Such impairment may be a cause of failure of pollinations, but assignment of failure to such causes must be attended with certain elements of uncertainty, because of the practical impossibility of establishing, in definite manner, the connection between the forces acting in one season, and the results attained in the next.

Injury from Winter Cold.—Low temperatures in winter are more frequently destructive to pistils than to stamens. The injury is easily detected when severe enough to blacken stigmas, but winter cold is frequently suggested as a cause of failure to fertilize in cases where flowers open normally and stigmas appear healthy. It is not unreasonable to assume that there may be injury to floral parts, but a certain degree of uncertainty must attach in such cases; the injury is assumed rather than proved.

Injury from Spring Frosts.—Styles and stigmas are delicate organs. When denuded of the protective bud scales and fully exposed by expansion of the floral envelope they are open to injury by frosts, which may cause failure by preventing fertilization, or may kill the ovary after fertilization has taken place. Spring frosts as causes of failure of pollinations are definite. They come at times when blossoms are receiving attention, effects are subjected to critical examination, and assignment of failure to this cause is, usually, made quickly and positively.

Cold Rains and Wind.—Cold rains when protracted and accompanied by high winds may so injure pistils as to prevent fertilization, and the vitality of pollen sometimes appears to be injured by these agencies. Often flowers are whipped about by winds in such manner as to cause mechanical injuries. In some seasons failures from this cause are many.

Imperfect Pollen.—Apple trees in the adolescent state commonly flower for one or two years without producing fruit. The vegetative function is still ascendant, and adjustment of balance with the reproductive function has not been perfected. The flowers appear nomal, but produce stamens whose anthers do not dehisce normally, and which are either empty or partially filled with pollen so imperfectly formed as to be incapable of performing its proper functions. Imperfect pollen also occurs in flowers of mature trees. Some varieties, in some years, have so large a proportion of defective grains that use of the pollen invariably results either in entire failure or in a very low percentage of success. The low record of Stayman Winesap is due to defective pollen. This variety has been used as the pollen parent in twenty-four crosses, on nineteen forms of Malus that have involved 559 pollinations. Thirteen of the crosses, involving 197 pollinations, failed entirely; one cross, with 6 pollinations, yielded 2 fruits containing no seeds; four crosses, involving 200 pollinations, yielded 5 fruits containing 10 seeds, none of which germinated; two crosses, with 111 pollinations, yielded 38 fruits containing 49 seeds, 9 of which germinated, but the seedlings died very soon after appearance above ground; one cross, with 21 pollinations, yielded 8 fruits with 27 seeds, 14 of which germinated; nine seedlings were moved to nursery, but the last one died before the end of the fourth year. Thus twenty-one of the twenty-four crosses are eliminated; the other three, with 84 pollinations, yielded 26 fruits containing 54 seeds, 25 of which germinated; eleven seedlings are now living at nine years of age; three of the seedlings are doubtfully graded as good, four as fair, and four as poor.

One of the crab-like forms of Malus that came to the collection as *Malus ringo sublobata* never produces any viable pollen; the anthers are small, do not dehisce, and when broken up mechanically yield none but defective grains of pollen.

Accidents.—During the period between pollination and maturity of fruit, accidents are likely to occur, often in sufficient numbers to increase materially the percentage of failures. Fruit spurs are easily broken and individual flowers are often injured by improperly adjusted bags. Some accidents are due to storms and wind and are unavoidable, but the number that occur can be reduced by careful selection of clusters to be pollinated and by extreme care in the performance of all operations. In a few cases failures have been definitely traced to injuries inflicted by the tool used in emasculating; in other cases this cause was suspected but could not be proved because the evidence of injury had been destroyed by drying out before the time of examination.

THE PLANT BREEDING HOUSE

The pollination work thus far referred to has applied only to work done in the orchard. This has been attended with much discomfort and many disappointing results; it comes at a season when fluctuations in weather are often sudden and severe, when high winds are common, showers frequent, and temperatures often low. Emasculation and pollination have been attempted when fingers were so numb that the bags were tied with difficulty and the other more delicate operations performed in a very unsatisfactory manner. Repeated discouraging experiences led to a request for a glass house in which trees could be brought to flower and where the work of pollination could be carried on under perfectly controlled conditions of temperature and moisture.

The Department of Horticulture had two greenhouses, each 20 by 50 feet, that had been constructed for floricultural work. These were fitted with permanent benches, having low side-walls, and were well adapted to the culture of small plants but not suitable for the growth of fruit trees.

When construction of a new house was authorized, search was made for a model with high side-walls, something that would fill the needs as then understood, but nothing could be found and finally plans were drawn that were modeled in part after a description of a greenhouse in use at the German Experiment Station at Bernburg as given by Professor Helriegel in the Experiment Station Record for February, 1894.

Construction was begun early in the summer of 1912 and the house was ready for occupancy by the end of the year. As built, the plant consists of the main glass house 30 by 80 feet, to which is joined, on the west at the north end, a forcing house 28 by 80 feet, which extends to a cross house or glass-covered corridor connecting with the service building at the north and affording exit to the yard on the south. At the south end of the larger glass house is a wire-covered steel frame house of the same height and floor space as the glass house. The side-walls of the larger glass house consist of 10 feet of glass resting upon a concrete foundation wall 2 feet high; the glass portion is divided midway by a horizontal bar to which the lower sashes, each 5 feet wide by 8⅓ feet long, are hinged as ventilators. There are five of these vents on the west and nine on the east side, besides one of half the standard length on each side. At the apex of the roof on each side are nine ventilators, each 3 feet wide and 8⅓ feet long, and also one of half the standard length; all ventilators are controlled by ventilating machines which operate from the side-walls, thus leaving the floor space clear of supports. At each end are six doors arranged in three pairs; each door is 3⅓ feet wide by 12 feet high, thus opening almost the entire ends from the concrete sill at the floor level to the full height of the side-walls. The heavy hinges are bolted to the

upright steel division bars which do not allow sagging, and the doors open easily. The ventilation facilities allow that degree of openness that is necessary during the still, clear days in early spring when action of the sun on the glass roof elevates inside temperature beyond the limit that is best for the trees.

Heating pipes are arranged against the concrete side-walls and at each end; between the pairs of doors are two radiators for use in

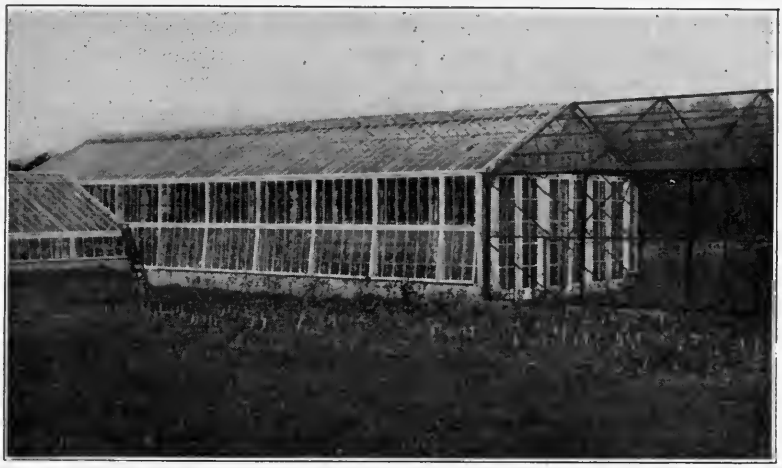

FIG. 4.—PLANT BREEDING GREENHOUSE AND PORTIONS OF ADJOINING HOUSES
This house was constructed in 1912. The high side-walls are an essential feature of the building.

emergency. No benches are used but all trees grown in the house are in pots which are plunged in rows as convenient.

The smaller glass house has concrete side-walls 3½ feet high upon which rests the glass walls 2½ feet high; these are hung in sections, the entire length on both sides. The ventilators and the roof ventilators are the same as provided in the larger house.

The wire house built as an extension to the larger glass house consists of a steel frame over which wire screen of ½-inch mesh is placed. This is used as a safe shelter for plants which are moved out from the glass house after danger of frost is past. The pots containing the trees are plunged as in the glass house. Here the fruits resulting from early spring pollinations are brought to maturity protected from birds and from severe winds. Fig. 4 is from a photograph of the main house with portions of the attached houses, taken October 25. Interiors of the glass house in spring and the wire house in summer are shown in Figs. 5 and 6.

Eleven years' experience with the structures described has suggested no material change in construction; they have proved very

satisfactory in all respects. The steel frames are so constructed that there is little interference with light; they are strong and of pleasing

FIG. 5.—INTERIOR OF PLANT BREEDING GREENHOUSE, MARCH 15

Concrete foundation walls 2 feet high support 10 feet of glass, portions of which are hinged and serve as ventilators. Ventilators in the roof are controlled by machines which operate from the side-walls, thus leaving the floor space clear of supports.

lines. Floor space is unobstructed by supports, allowing convenient arrangement of plants, which may be changed at will to suit circumstances.

The operations of emasculation and pollination are done in the house, not only more comfortably but with greater accuracy than is possible when perched on a ladder among the branches of orchard trees, particularly when winds are blowing and temperatures are low. The small, potted trees are easily moved about and can be placed in positions most convenient for working on particular clusters. The operator may sit comfortably, with a stand at hand for record and

tools, and thus be able to concentrate his energies and perform the work in the best possible manner. The danger of contamination by undesired pollen is reduced to a minimum; there are no accidents from wind and rain and a much higher percentage of success is attained than is possible when the work is done in the open orchard.

This is not to say that no failures occur in pollination under glass; failures do occur, sometimes many of them; certain combinations attempted either fail entirely, or give only a low percentage of

FIG. 6.—INTERIOR OF THE WIRE HOUSE SHOWN IN FIG. 4 AT THE RIGHT OF THE MAIN HOUSE

Plants moved out from the main house after danger of frost is past are sheltered here. The fruits resulting from early spring pollinations are brought to maturity protected from birds and severe winds.

success whether the work is done under glass or in the orchard. In these cases the difficulties lie with the plants themselves, and the causes of failure have nothing to do with surrounding conditions. Some plants are habitually poor breeders, and improvement in conditions under which the work is done does not effect a corresponding improvement in breeding results. Comparisons of particular combinations made both in the orchard and under glass almost invariably show much better results where conditions are controlled than where the work is done in the open.

COLLECTING TREES FOR FORCING PURPOSES

In anticipation of the construction of a greenhouse, the preparation of plants was begun in the spring of 1910. Paradise and Doucin

stocks were potted in 8-inch pots and grafted with scions from available species of Malus and from orchard varieties. Additions were made in 1911, including a few plants grafted with scions from hybrids from crosses of 1909. The pots were plunged outside in summer; late in the fall they were bunched together and mulched to guard against too severe freezing, and in January, 1913, were brought into the house and kept under moderate heat. There were 95 trees in all, representing 46 crab-like forms of Malus, 19 orchard varieties, and 7 hybrids from crosses made in 1909. Fourteen of the forms of Malus and one orchard variety bloomed in March, and 567 flowers were pollinated and yielded 173 fruits; a ratio of fruits to pollinations of 1 to 3.27. Four of the combinations attempted, involving 43 flowers, failed entirely. The remaining fifteen combinations gave percentages of success ranging from 3 to 98. The highest percentage was attained in crossing *Malus baccata oblonga* (811) by Yellow Transparent; 49 flowers pollinated gave 48 fruits yielding 319 seeds, 100 of which germinated, and 33 trees, now ten years old, are living. Owing to the small amount of bloom in this first season of work under glass, some difficulty was experienced in obtaining pollen of desired kinds at the time when wanted, and in consequence some of the matings were such as would not have been chosen had pollen of other kinds been available. All that could be done was to utilize such pollen as could be obtained.

In succeeding seasons, with increased numbers of trees and many more trees flowering, the difficulty of obtaining desired pollen became less and in the spring of 1916 disappeared; there were then, and have been in later seasons, more flowers produced than could be utilized, and there has been little difficulty in obtaining pollen of the kind and at the time wanted. Last season there were in the houses 573 trees, which classify as 407 hybrids, 86 representing 46 forms of Malus and 80 representing 35 orchard varieties. On these plants 169 crosses involving 2,151 pollinations were made, and 471 fruits were harvested. The success percentage is 21.89, which is quite low, owing to an unusual number of attempted crosses that failed entirely.

The houses are now filled to capacity and the trees flower abundantly each spring. That they succeed reasonably well on dwarf stocks is evidenced by the fact that there are living in the house 60 trees that were grafted in the spring of 1910 and are now fourteen years old.

In grafting hybrids on dwarf stocks the expectation was that earlier fruiting would be induced and thus hasten the starting of the second generation, but thus far experience in this direction has been somewhat disappointing. Of seven trees from scions of hybrids of 1909, grafted in the spring of 1911, one that fruited in 1916 at six years from graft has fruited each year since and appears as a parent in

a number of second-generation crosses. Two other trees fruited for the first time in 1918, one in 1919, and one in 1922. There are still two trees that altho thirteen years from graft have not yet flowered or fruited.

This record is very little better than the record of the seedlings in orchard. In the house as dwarfs, one of seven fruited in the sixth year, while in the orchard one of ten seedlings fruited in the sixth year. Not one of the seedlings from which scions were taken flowered, but for five of the seven trees in the house there were sister trees in the orchard that did flower; that is, other individuals from seeds of the same fruit. The paradise stocks on which the scions were grafted were of French origin, and while nothing is known of the particular strain of Malus from which they came, it has appeared that they exercised the dwarfing influence on scion growth that is commonly associated with paradise stocks. They do not in this case, however, appear to have exercised any influence in the direction of earlier fruit production.

COLLECTING BREEDING MATERIAL

ORCHARD VARIETIES

Trees Available in 1907

When apple breeding was commenced in 1907 the departmental orchards of bearing trees, which had been seriously depleted by necessary extensions of the University campus, consisted of two blocks or plats: Plat A with 141 trees representing 102 varieties, a large proportion of which were of Russian origin, and Plat C with 119 trees representing 28 varieties, most of which were such as are commonly planted in Illinois orchards.

Two rows of younger trees in Plat D, with 19 trees of 13 varieties not elsewhere represented and including Ingram, Beach (Apple of Commerce), Springdale, Oliver, Fanny, and Arkansas (Mammoth Black Twig), began flowering in 1911 and in that and the two following years were used to some extent, so that part of these varieties appear in the list of varieties used as parents, but in the fall of 1913 these trees were removed.

In 1904 a tract of approximately ten acres was planted with 306 trees representing seven varieties; namely, Jonathan, Ben Davis, Oliver, Black Ben Davis, Jefferis, Grimes, and Collins. This is known as the "Commercial Orchard." The trees began flowering in 1913 and, in the years since then, selected individuals have been used as parents in breeding.

Additions Since 1907

It was foreseen in 1907, at the time apple breeding was begun, that the two plats of bearing trees would be absorbed in campus

extensions within a few years and that it would be necessary, in order to provide trees for use in continuation of the breeding projects undertaken, to secure other areas so situated as to insure permanency of plantations made, and then to plant these areas with the varieties desired for breeding purposes. No land was available at this time, but it was thought best to buy the trees and hold them in the nursery until such time as land could be obtained for orchard purposes.

To this end a list was made which included varieties known to have been thoroly tested in the state, which had received the endorsement of the State Horticultural Society. To this were added a few varieties, such as Baldwin, King, and Rhode Island Greening, not commonly planted in Illinois but desired as part of a breeding collection. The list, which included 37 varieties, follows:

Summer		*Autumn*	
Benoni	Oldenburg	Chenango	McIntosh
Bough	Red Astrachan	Dyer	McMahon
Early Harvest	Red June	Fameuse	Mother
Golden Sweet	Sops of Wine	Longfield	Ramsdell Sweet
Keswick	Yellow Transparent	Maiden Blush	Wealthy

Winter

Baldwin	King	Pewaukee	Tolman
Ben Davis	Minkler	Ralls	Westfield
Domine	Northern Spy	Rhode Island Greening	Wellow
Grimes	Northwestern Greening	Salome	Winesap
Jonathan			

Copies of this list were sent, with orders for one tree of each variety, to nine nurseries: one in Canada, the others distributed in seven states from Maryland to Kansas.

This distribution of prospective parent trees was adopted in order that trees of the same variety from widely separated localities might be grown contiguously for convenience of observation, for the purpose of determining whether or not there exist tangible differences indicating well-defined strains in any or all the varieties. Incidentally, opportunity was offered for direct comparison of trees grown in nurseries remote from each other with markedly different soils and under different climatic conditions. This comparison proved interesting and showed very conclusively that there are decided differences in nursery trees from different sections. These differences were most apparent in color of bark, in size, and, most important, in root systems.

The trees were all two years from graft or bud, and when those from different sources were placed side by side, whether compared by single varieties or by entire lots, the differences in most cases were constant. Naturally there were, in the nine groups of trees, extremes and intermediates. Here were two lots that illustrated the extremes: one lot with trees all below medium in size for two-year-old trees, the

bark light in color and dull, and the roots consisting of a few short stubs with few or no fibrous roots; the other lot of the same age consisting of trees above medium in size and yet not having the appearance of overgrown trees, bark bright, of decidedly darker color, and the root systems masses of small roots abundantly supplied with fibrous roots. Manifestly the two lots of trees were grown on very different soils. The small trees with no small roots were grown on infertile soil that made it necessary for the trees to forage at a distance for food and extend the roots so that most of them were left in the ground when the trees were dug. The other lot, on soil of abundant fertility which was near at hand and readily available, produced masses of small roots immediately about the central roots, and these masses went with the trees when they were removed.

No one called upon to choose between the two lots of trees would hesitate in accepting the large trees with abundant roots as best. When planted, these trees started growth earlier and with more vigor than did those with deficient root systems. This advantage gained in the early years has been generally maintained; there are, however, some cases in which small trees with few roots have appeared to increase in vigor with age and are now equal in growth with those which were most vigorous when planted. Records of these trees have been maintained and their fruiting qualities, differences within varieties, and evidences of definite strains will be given attenton in a future paper.

Not all the trees ordered were received. The complete list of 37 varieties would have given 333 trees, but only 218, or approximately 65½ percent of the number ordered, were received. Not one of the nurseries was able to fill the complete list. One variety, Dyer, was not in stock in any of the nurseries and hence was dropped from the list. Mother was received from only one nursery, and the same is true of Westfield. Only two of the nurseries could supply Ramsdell Sweet and Willow; only three supplied McMahon and Keswick; four nurseries, Benoni, Golden Sweet, Sops of Wine, and McIntosh; five supplied Longfield and Domine; six supplied Bough, Red June, Chenango, Minkler, Ralls, Rhode Island Greening, and Salome; seven supplied Early Harvest, King, Northern Spy, Pewaukee, and Tolman; eight supplied Maiden Blush, Wealthy, Baldwin, Jonathan, and Northwestern Greening. All the nurseries supplied the following 7 varieties: Oldenburg, Red Astrachan, Yellow Transparent, Fameuse, Ben Davis, Grimes, and Winesap.

The nurseries were rather widely distributed and the trees received served to show, for the varieties here included, which were most frequently and which least frequently grown. Of the nine nurseries, one supplied 29 varieties; one, 28 varieties; two, 26 varieties each; one, 23 varieties; and one, 13 varieties. One nursery in making shipment included one tree each of three varieties for trial; these were

Dee's Seedling, Kinnard, and Wandering Spy. One of the lots of trees included two trees of Winesap instead of one. This brought the aggregate of trees to 222 and that number was planted in the nursery, April 19 and 20, 1907.

It was expected that land could be secured so that removal to orchard could be made the following spring, but this did not prove possible and it was not until the spring of 1909 that the desired land became available. The trees were removed and planted 30 by 30 feet apart, April 15 to 19, 1909. The number thus transferred was 198, showing a loss during the two years in nursery of 24 trees, or nearly 11 percent. A few of the trees planted in the nursery did not start growth, others died at intervals, some from blight and some from other undetermined causes. The loss included three trees each of Baldwin and Minkler, two each of Maiden Blush, Wealthy, Early Harvest, and Red June, and one each of ten other varieties.

In addition to the trees purchased in 1907 there were planted in orchard at the same time 43 trees representing 20 varieties from another station nursery. This addition consisted of trees remaining of a lot of certain varieties propagated for other purposes in 1905 from scions received from various sources. Some of these varieties were already represented in the planting, but the following were new to the collection, Wolf River, Roe's Duchess Seedling, Stark, Columbus Red, Water, Sweet Bellflower, McClellan, Red Stripe, American Summer Pearmain, Higby Sweet, Hyat's Wonderful, Howard's Sweet, and Buler (Syn Jonathan [of Buler]). Scions of four additional varieties—Akin, Fanny, Delicious, and Stayman Winesap—were obtained from Mr. George W. Endicott of Villa Ridge in the spring of 1908. These were root-grafted on seedling stocks, grown in nursery for that year, and planted in orchard with the other trees in the spring of 1909, an addition of 28 trees. To the orchard varieties here enumerated may be added as a portion of the 1907 purchase, one tree each of the garden crabs, Martha, Florence, General Grant, Soulard, Hyslop, and Transcendent.

Five trees died during this first season in the orchard and the vacancies were filled in the spring of 1910 with Black Ben Davis. One of these trees died and in the three following years seven additional vacancies occurred, mainly thru attacks by blight. These vacancies were filled in 1914 with trees sent to the Station for trial by Stark Brothers of Louisiana, Missouri; the varieties represented by two trees each are Old Wife Pippin, Ohio Dark Red Rome Beauty, Ohio Nonpareil, and Salome, all but the latter being new to the collection.

Thus this block of apple trees planted and grown especially for breeding puposes consisted of 269 trees representing 64 varieties of apples and 6 crabs.

Flowering of the Trees

The first bloom of the block appeared in 1912, when 2 of 3 trees of Keswick, 1 of 8 Yellow Transparent, 2 of 6 Maiden Blush, 1 Wandering Spy, and 2 of the crabs—General Grant and Florence—each produced a few clusters; but in no case did fruit mature. The trees were then seven years old. In the following year, 1913, the list of trees producing bloom was considerably extended. Of 89 trees representing 14 varieties, 43 are of record as having flowers, but only one tree—one of five Longfield—had flowers sufficiently perfect and numerous enough to warrant its use in breeding. Forty-five emasculated buds in twenty-five clusters on this tree were bagged April 28, 1913, and pollinated with Jonathan pollen on May 2; on June 20, 15 fruits appeared to be developing, but only 10 mature fruits remained at picking time, September 9. Seedlings were grown from seeds of these fruits, planted in orchard in 1916 and 39 of them, now ten years old, are living. Other trees that matured fruits in 1913 are 2 of 3 Keswick, 4 of 9 Oldenburg, 10 of 11 Yellow Transparent, 2 of 5 Maiden Blush, 1 of 7 Tolman, 1 of 7 Jonathan, and 4 of 6 Roe's Duchess Seedling.

Other trees began flowering in the succeeding years, and in the seventh year from planting in orchard a number of trees produced small crops. The flowering record for 1916 records 88 percent of the trees in the block as producing flowers, the amount ranging from a few clusters on trees flowering for the first time, to full bloom for many that began flowering in earlier years. There have been some laggards, trees that were very tardy in beginning flowering and did not reach full bloom until they were far past the age at which bloom should be expected. A few trees altho now nineteen years old and growing in orchard for fifteen years have produced no flowers; these are 2 of 4 Benoni, 2 of 6 King, and 3 of 7 Northern Spy. Evidently these varieties are not adapted to conditions in this locality. Certain individuals in other varieties have never reached satisfactory bloom, notably 1 of 3 McIntosh, 1 of 4 Golden Sweet, 1 of Rall's, and 1 of Salome; these trees have, for several years, produced a few flowers each season, but never in quantity to promise a crop.

The non-flowering trees are so evenly distributed with regard to region of origin that there is no ground for suspicion that place of origin is in any way responsible for retarded and scant flower production, and, except for the possibility that they may be incorrectly named, there appears no reason for their behavior other than individual peculiarity.

For several years this plantation has had sufficient trees in fruiting condition to supply all possible needs of breeding material of this class; there is wide range in such characters as season, color, size, and quality. The combinations that may be made for test of specific

characters are almost endless, certainly beyond what it is desired to attempt.

SPECIES AND VARIETIES OF MALUS

Scions from U. S. Department of Agriculture

The third division of the apple-breeding project covers reciprocal hybrids between orchard varieties of apples and such other species and forms of the genus Malus as can be brought to flowering. At the time of beginning breeding work, Whitney and Yellow Siberian Crab were the only representatives of forms other than orchard varieties and an effort was made to secure additional kinds. In response to a request, the Bureau of Plant Industry of the U. S. Department of Agriculture very kindly sent to this Station, for the breeding work, a package of scions that had been presented to the Department by Dr. Sargent of the Arnold Arboretum.

This package contained scions of sixty-two species and varieties of Malus under the departmental accession numbers 19630 to 19691, and was received January 29, 1907. Unfortunately the scions, when received, were in such a dry condition that it was believed none could live. They were immersed in water for a time and then packed away in damp sphagnum moss until such time as grafting could be performed.

The list of forms, with comments, as received from the U. S. Department of Agriculture was as follows:

19630 to 19691 *Malus sp.*
From Jamaica Plain, Mass. Received thru the Arnold Arboretum, January 7, 1907.

19630 *Malus sargenti,* discovered by Professor Sargent in a salt marsh near Moronan, Japan, in 1892. It is a rather small shrub but very ornamental in flower.

19631 *Malus sylvestris,* sometimes called *M. acerba,* and by the older botanists was considered a form, at least, of the common apple.

19632 *Malus crataegifolia,* sometimes called Cormus; it is a rare Italian tree.

19633 *Malus spectabilis,* unknown in cultivation, and supposed to be a native of China.

19634 *Malus zumi* (not *xurui*) is a native of the mountains of Japan, where Professor Sargent found it in 1892 and introduced it into cultivation.

19635 *Malus baccata* is the small fruited crab of eastern Siberia.

19636 *Malus atrosanguinea* is probably a hybrid between *M. toringo* and *M. floribunda.*

19637 *Malus baccata* X *Malus* X X (3549)

19638 *Malus prunifolia frutico coccinea*

19639 *Malus denticulata*

19640 *Malus cashmerica* is a Himalayan species. It is growing well at the Arnold Arboretum and is interesting as one of the few Himalayan trees that flourish in this climate.

19641 *Malus coronaria,* the common species of the eastern states.

19642 *Malus baccata sanguinea*

19643 *Malus siberica frutico coccinea*

19644 *Malus microcarpa*
19645 *Malus malus*, extra fruiting variety
19646 *Malus scheideckeri*, a very fine seminal form of the double *M. spectabilis*
19647 *Malus siberica*. Professor Sargent states that he does not know this, but it is probably a baccata.
19648 *Malus baccata prunifolia*
19649 *Malus rivularis* var. Described by Professor Sargent as a very interesting plant indeed, raised at the Arnold Arboretum from seed collected many years ago in Oregon. It is quite distinct from *M. rivularis* and gives some evidence of being a hybrid. It has not yet been described or named.
19650 *Malus prunifolia*, extra red fruit, is a Siberian species, according to Professor Sargent.
19651 *Malus arnoldiana*, is a seedling of *M. floribunda* that originated in the Arnold Arboretum and shows the influence of the blood of *M. prunifolia* by its larger flowers.
19652 *Malus toringo*, is the common north China species with both red and yellow fruits.
19653 *Malus baccata oblonga*
19654 *Malus toringo*, yellow fruit
19655 *Malus prunifolia xanthocarpa*
19656 *Malus floribunda*, probably a Chinese plant, altho it was introduced into Europe and the United States from Japan. It does not appear to be known in a wild state.
19657 *Malus spectabilis* var. 459-1
19658 *Malus ringo*, probably Japanese
19659 *Malus spectabilis*
19660 *Malus baccata* var.
19661 *Malus baccata* X *floribunda*
19662 *Malus ringo*
19663 *Malus baccata aurantiaca*
19664 *Malus toringo*, a dwarf form of No. 19652 raised at the arboretum from Chinese seeds.
19665 *Malus soulardi*, the well known species or hybrid, as some authors believe, of the Central West
19666 *Malus baccata* var. Hillside, bright red fruit
19667 *Malus malus*, bright red fruit
19668 *Malus rivularis*, the common wild crab of the Northwest
19669 *Malus malus* 444/1
19670 *Malus astrachanica*
19671 *Malus malus* 441/2
19672 *Malus prunifolia, Rubia cerasiforme*
19673 *Malus sp.* (?) var. Rones crab (Ottawa)
19674 *Malus ioensis*, the common crab of the Central West
19675 *Malus prunifolia flava*
19676 *Malus angustifolia*, the crab of the southern states, getting north into Missouri and Pennsylvania
19677 *Malus baccata maxima*
19678 *Malus malus* X *baccata*
19679 *Malus malus fl. pl.*
19680 *Malus malus fastigiata bifera* 538-2
19681 *Malus halliana*, of which *M. parkmani* is a synonym, is also Chinese, altho it was probably first introduced from Japan; it is unknown in the wild state.
19682 *Malus baccata* var.
19683 *Malus niedwietzkyana*, a Turkestan tree and probably a form of the common apple.

19684 *Malus spectabilis* var. 766/1
19685 *Malus baccata* X *toringo*
19686 *Malus ringo incisa*
19687 *Malus kaido*
19688 *Malus pendula,* the weeping form of the common apple
19689 *Malus ringo sublobata* 4645 Spath
19690 *Malus prunifolia macrocarpa*
19691 *Malus sp.* 5004 No. 5

Top-Grafts.—Forty-four scions representing thirty-two of the serial-numbered species or forms were top-worked March 22, 1907. The stocks used were young trees of Sops of Wine and Fameuse that had been crown-grafted on Virginia Crab seedling stocks three years previously, and which were at this time growing in Plat I, 5 feet apart in rows 10 feet apart. The scions were in very poor condition; they had not recovered from drying while in transit, they were not of normal plumpness, and the expectation that few would grow was fully realized.

Only the following were living on October 9, the time of final examination for that season:

19683 *Malus niedwietzkyana*.....1 scion
19651 *Malus arnoldiana*.....1 scion
19643 *Malus siberica frutico coccinea*.....2 scions
19670 *Malus astrachanica*.....1 scion
19689 *Malus ringo sublobata*.....1 scion
19662 *Malus ringo*.....1 scion
19631 *Malus sylvestris*.....1 scion

The grafts continued to grow and serve as the source of scions for further propagation so that the forms listed as living are now established in the collection and are fruiting regularly each season.

Root-Grafts.—Root-grafts on ordinary apple seedling stocks were made March 23, 1907; sixty of the sixty-two serial numbers were represented by from one to four in a total of 126 grafts. These grafts were packed in damp sphagnum moss until April 29, when they were planted in nursery. Very few of the scions started growth. When checked on July 20 only 21 grafts representing fourteen serial numbers were living and most of these were weak. The living grafts were lifted for winter storage and again planted in nursery in the spring of 1908. When taken up in November, 1908, 16 grafts representing eleven serial numbers were living; these were again grown in nursery during 1909 and after another winter in storage were planted in the orchard April 27 and 28, 1910.

The root-grafted trees thus planted in orchard were as follows:

19630 *Malus sargenti*.....1 tree
19644 *Malus microcarpa*.....2 trees
19646 *Malus scheideckeri*.....1 tree
19651 *Malus arnoldiana*.....1 tree
19662 *Malus ringo*.....1 tree

19664 *Malus toringo*.....2 trees
19665 *Malus soulardi*.....1 tree
19667 *Malus malus* var.....1 tree
19669 *Malus malus* var.....2 trees
19688 *Malus pendula*.....2 trees
19689 *Malus ringo sublobata*.....2 trees

Thus at the close of 1907, living representatives of 15 of the 62 kinds sent as scions were divided as follows:

Represented by root-grafts only

19630 *Malus sargenti*
19644 *Malus microcarpa*
19646 *Malus scheideckeri*
19664 *Malus toringo*
19665 *Malus soulardi*
19667 *Malus malus* var.
19669 *Malus malus* var.
19688 *Malus pendula*

Represented by top-grafts only

19631 *Malus sylvestris*
19643 *Malus siberica frutico coccinea*
19670 *Malus astrachanica*
19683 *Malus niedwietzkyana*

Represented by top and root-grafts

19651 *Malus arnoldiana*
19689 *Malus ringo sublobata*
19662 *Malus ringo*

Less than 25 percent of the forms were successfully perpetuated; this is a very low percentage, but really higher than was expected judging from the condition of the scion material when received.

Scions from Arnold Arboretum

The fifteen kinds surviving served as an acceptable beginning to the collection of forms of Malus, but in view of the very great number of published species and varieties included in the genus, could be regarded only as a beginning; more forms were desired. Therefore, in the fall of 1907, an appeal was made direct to Dr. C. S. Sargent of the Arnold Arboretum. In response to this appeal a package of scions was received on January 9, 1908, representing fifty-seven different species and varieties of the genus. The scions were cut, shipped immediately, and when received were in excellent condition; they were labelled with name only; thus the first procedure was to provide serial numbers. This course is followed with most plants in experiment station plantations because of simplicity, economy, and decreased liability to error. Where several kinds of plants are used, each handled in considerable numbers, the task of secure labelling is a serious one, and abbreviation within the limits of certain recognition deserves most careful attention. If a number of three or four digits can take the place of a binomial of twelve to eighteen letters, or a trinomial of twenty to thirty letters, the saving in the making of labels, in note-taking, and in some of the records is a large item.

Keys to names are, of course, necessary and at first are freely used, but in a short time the numbers and names become so well

associated in the mind of the worker that the briefer designation serves all purposes of references. In the present instance the scions were arranged alphabetically by name and then given numbers serially from 801 to 857. This soon became known, in any reference to these plants, as the "800 series," just as surviving plants of the lot received the preceding year, in which case the accession numbers as applied by the Department of Agriculture were retained, became known as the "19000 series." Neither series conflicts with other series of numbers in use, and in the 800 series the first digit serves as a perpetual reminder of the year in which the series was instituted. The list of scions received with the prefixed numbers as in the key in common use is as follows:

801 *Malus angustifolia*
802 *Malus arnoldiana*
803 *Malus astrachanica*
804 *Malus atrosanguinea*
805 *Malus baccata aurantiaca*
806 *Malus baccata,* red fruit 443-1
807 *Malus baccata,* bright red fruit, late
808 *Malus baccata* var.
809 *Malus baccata* var.
810 *Malus baccata maxima*
811 *Malus baccata oblonga*
812 *Malus baccata* X *prunifolia*
813 *Malus baccata sanguinea*
814 *Malus baccata* var. *sieboldi*
815 *Malus baccata* X *toringo*
816 *Malus cashmere*
817 *Malus crataegifolia*
818 *Malus coronaria*
819 *Malus dioica*
820 *Malus fastigiata bifera*
821 *Malus floribunda*
822 *Malus* Fluke apple
823 *Malus halliana*
824 *Malus* Hyslop Crab
825 *Malus ioensis*
826 *Malus ioensis fl. pl.*
827 *Malus kaido*
828 *Malus prunifolia macrocarpa*
829 *Malus malus* 441-1
830 *Malus malus*
831 *Malus malus* X *baccata*
832 *Malus pendula*
833 *Malus malus fl. pl.*
834 *Malus niedwietzkyana*
835 *Malus prunifolia*
836 *Malus prunifolia flava*
837 *Malus prunifolia macrocarpa*
838 *Malus prunifolia* (fine var.)
839 *Malus prunifolia xanthocarpa*
840 *Malus ringo*
841 *Malus rivularis*
842 *Malus rivularis* var.
843 *Malus sargenti*
844 *Malus scheideckeri*
845 *Malus sikkimensis*
846 *Malus soulardi*
847 *Malus spectabilis*
848 *Malus spectabilis* 615
849 *Malus spectabilis* var. 459-4
850 *Malus sylvestris*
851 *Malus toringo,* yellow fruit
852 *Malus toringo,* dwarf, spreading form
853 *Malus toringo,* red fruit
854 *Malus ringo sublobata*
855 *Malus zumi*
856 *Malus sp.* (?) 5004, yellow fruit
857 *Malus* Yellow Siberian Crab

Root-grafting on apple seedling stocks was begun January 11 and was finished January 20. The total number of grafts made was 570, an average of 10 for each number. This did not utilize all of the scion wood except for four numbers. In the period April 4 to 9 the remaining scions of 53 of the kinds were top-worked on young trees in Plat I. The grafts ranged from 2 to 15 for each species or variety, a total of 396. Twenty-three of the kinds were worked on Sops of Wine; 14 on Fameuse, and 18 on Virginia Crab seedlings.

In the fall of 1908 the number of root-grafts living was 144, representing 39 of the kinds grafted, and of the top-grafts, 176, representing 38 kinds, were alive.

Scions of nine of the series failed to grow either as root-grafts or top-grafts; these were:

805 *Malus baccata aurantiaca*
812 *Malus baccata* X *prunifolia*
815 *Malus baccata* X *toringo*
816 *Malus cashmere*
827 *Malus kaido*
828 *Malus prunifolia macrocarpa*
835 *Malus prunifolia*
844 *Malus scheideckeri*
847 *Malus spectabilis*

One, No. 845 *Malus sikkimensis*, root-grafted only, failed to grow. Thus 10 of the 57 numbers were lost, leaving 47 with living representatives at the end of the first season. Ten of these appear only in the list of root-grafts, 8 only in the list of top-grafts, and 29 have representation in both lists.

Six kinds under numbers of the 800 series had duplicates in the 19000 series; these were:

832 *Malus pendula*.....same as 19688
840 *Malus ringo*.....same as 19662
843 *Malus sargenti*.....same as 19630
846 *Malus soulardi*.....same as 19665
852 *Malus toringo*.....same as 19664
854 *Malus ringo sublobata*.....same as 19689

There are then five of the 19000 series to be added to the 47 kinds represented in the 800 series to make up the total of forms of Malus represented in the collection. These are *M. malus* 444/1 (19669), represented by two trees now fifteen years old from root-grafts. Neither of these trees has flowered as yet. *M. malus* var. (19667), a form that has flowered regularly and abundantly since 1913, the seventh year from graft, is a crab-like form quite distinct from any other form in the collection. *M. arnoldiana* (19651) is erroneously named. *M. arnoldiana* as 802 closely resembles *M. floribunda*, of which it is said to be a seedling, but 19651 is totally different in habit of growth, foliage, flower, and fruit. It is plainly a form of *M. prunifolia*, and in the list of descriptions it is placed as *M. prunifolia* var. (33), *M. scheideckeri* (19646), and *M. microcarpa* (19644).

To replace some of the kinds that failed in 1908 a further lot of scions representing eleven of the numbered forms was received from the Arnold Arboretum in the spring of 1912. These were numbered 1201 to 1211 and constitute what is referred to as the 1200 series. Three of these, namely, *M. baccata* var. (1202), the equivalent of 809, *M. baccata aurantiaca* (1203), the equivalent of 805, and *M. spectabilis* var. 459-4 (1211), the equivalent of 849, failed again; the remaining eight of the series are represented by 2 to 10 root-grafted trees now

twelve years old. Eliminating duplications there are now 51 kinds in the collections. This is more than enough for any breeding that is likely to be attempted, but falls far short of representing all the forms of the genus that have been dignified by specific or varietal names.

HYBRIDIZING: DIVISION INTO CLASSES AND GROUPS

What follows was written in 1917 and is an account of hybridizing done up to that time. Hybrid seedlings of known parentage from crosses made in the earlier years began fruiting in 1917, and nearly all crosses made in that and following years included as one or the other or both of the parents these hybrid seedlings. It is not the purpose of this paper to consider the work done with combinations involving these hybrid seedlings.

Hybridizing apples as practiced at this Station has involved two quite distinct classes of plants; namely, (1) orchard varieties and (2) crabs and crab-like forms of the genus Malus. Because of the differences between these plant classes, the combinations that have been attempted are classified for convenience into four groups as follows:

1. Orchard varieties X orchard varieties
2. Orchard varieties X crab-like forms
3. Crab-like forms X orchard varieties
4. Crab-like forms X crab-like forms

Groups 1 and 4 are combinations within the respective classes, while Groups 2 and 3 are combinations of the two classes. Group 3 is the reciprocal of Group 2 and for any particular pair combined in the two directions the gametic composition is the same and the progeny is expected to be similar. However, a marked difference in the degree of success attained in crossing in the two directions has been encountered in practice. Pollen of orchard varieties appears more acceptable to stigmas of crab-like forms of Malus than is pollen of crab-like forms to stigmas of orchard varieties. This fact, which developed early in the work, has led to the pollination of many more flowers of crab-like forms than of orchard varieties. It should not be understood, however, that all or even a very large proportion of attempts to hybridize orchard varieties by pollen from crab-like forms fail; some such combinations have been highly successful, but considering the aggregate of attempts in the two directions the results warrant the statement as made. The ratios of fruits to flowers were, for crab-like forms X orchard varieties, 1 to 4.41, and for orchard varieties X crab-like forms, 1 to 6.29. No structural differences have been discovered that can in any way account for the frequent difference in behavior of pollinations in the two directions, but the fact is well established that it is easier to hybridize crab-like forms successfully by pollen of orchard varieties than it is to produce fruits by the reverse process.

Nearly three times as many combinations have been made in Group 1 as in Group 4, and the number of flowers of orchard varieties pollinated in Group 1 is seven times greater than the number of flowers of crab-like forms pollinated in the combinations of Group 4. This is partly because orchard varieties have been available since the work

began, while considerable numbers of the crab-like forms have become available only during the later years, and partly because the chief effort has been directed towards combinations of orchard varieties and to securing hybrids between orchard varieties and the crab-like forms. Combinations of crab-like forms have been neglected; perhaps as much because of their deficiency in economic value as for any other reason, altho such combinations are certainly equal, if not superior, to combinations of orchard varieties for studies of character transmission. These crab-like forms have more distinctly marked differentiating characters than have the orchard varieties, and the different forms of the group hybridize even more readily than do orchard varieties.

In the hybridizing thus far done there have been used 43 orchard varieties and 49 crabs or crab-like forms of Malus. The numbers of parental combinations in the several years range from 28 in 1909 to 235 in 1916. The aggregate of these yearly totals is 744, but many of the combinations have been attempted in more than one year; eliminating these duplications it appears that the aggregate of distinct parental combinations is 630 for the seven years. The total of flowers pollinated is 34,347, the number of fruits having viable seeds 6,619, a ratio of fruits harvested to flowers pollinated of 1 to 5.19. In the account to be given of the hybridizing attempted during the seven years thru which the work extended, it will be convenient to maintain the division into the four groups that have been mentioned, considering the first group No. 1.

GROUP 1: ORCHARD VARIETIES X ORCHARD VARIETIES

Hybrids in this group are between such varieties as have been available in the Station plantations. The combinations made have all had as an objective the testing of stability, potency, and manner of transmission to progeny of tangible parental characters. In most cases choice of parents has been based upon specific characters such as size, color, flavor, and season of fruit, character of foliage, or habit of growth of tree. Varieties producing large fruits have been paired with varieties producing large fruits and with varieties producing small fruits. Red color of fruits has been paired with red color and with yellow; yellow with yellow and with red; sour with sour and with sweet; summer with summer, with fall, and with winter. In many cases the crossing has been reciprocal.

There appears to be no basis other than visible characters upon which to rest choice of parents. Except that Ingram is said to be a seedling of Ralls, and Isham a seedling of Bailey Sweet, nothing is known of the immediate parents of the varieties used, and as to the ancestry of parents no records whatever are available. Most varieties are discovered or resurrected. When one interested in fruit and on the watch for new things visits or chances to pass a long neglected

farm orchard near the time of fruit maturity, he notes an individual tree the fruits of which are attractive. He takes scions, propagates them, brings trees to fruiting, attaches a varietal name, advertises and disseminates it as a new variety. Probably the tree thus discovered was planted from three to five decades previously; it may have been imported from a distant state and planted as a named variety selected because of its known or reputed good qualities. No record is kept. The owner who did the planting gives attention to his trees and takes pride in them for some years, then dies, migrates, or sells the property; neglect follows and most trees die; the survivors pass from one owner to another until the time of rediscovery and resurrection. To how many varieties of today such a history would apply is, of course, unknown, but it seems at least probable than many of the new introductions of the last fifty years may have had similar histories.

Some varieties are assigned to origin as "chance seedlings." These are discovered in the same manner as the varieties referred to as having been resurrected, and for all that is definitely known may actually belong to the same class, for to say of a mature fruiting tree growing in a fence corner or in some out of the way place that it is a chance seedling is merely an assumption in the absence of any historical facts. Division fences are sometimes changed and it does not take long to develop an appearance of long neglect in a fence row; so too, a fine orchard may in a few years become a typical "waste place." Few of our varieties have definite histories and not one has a known pedigree.

Origin of Cultivated Varieties

All orchard varieties are classed under the one species *Pirus malus,* as established by Linnaeus in the first edition of his "Species Plantarum" of 1753. Presumably Linnaeus based the species upon some form or forms of the wild apple commonly found in most parts of Europe. When the genus Malus, which was first established by Tournefort[1] in 1700, but by succeeding botanists, including Linnaeus, relegated to a section under the genus Pyrus, was resurrected a few years since, the common apple became *Malus malus,* and that is now the commonly accepted name. Present day varieties have come down to us thru centuries of cultivation. The beginning of domestication of the apple is unknown; even the most ancient writers who mention the apple treat it as a cultivated fruit. De Candolle[2] included the apple among those plants cultivated for more than four thousand years and says, "I consider the apple to have existed in Europe, both wild and cultivated, from prehistoric times."

Professor Karl Koch, from studies based upon observations and plant material collected during extended travel in the eastern parts of

[1]Tournefort, J. P. Inst. Rei Herb. 1700.

[2]Koch, Karl. Origin of Cultivated Plants, Eng. ed., 236. 1886.

the Caucasus, Mongolia, Tartary, and certain Chinese provinces, arrives at the conclusion that the apple was not originally wild in Europe. He says,[1]

"So much seems to me certain, neither the apple found here in Europe, called wild apple, nor the pear-like races are to be regarded as species. We have looked at them only as wild plants. Neither the apple nor the pear were originally wild in Europe. This assertion is confirmed by this, that the many wild apples and pears themselves do not, as a rule, resemble each other."

Professor Koch recognizes the difficulty of ascertaining with certainty the species from which the cultivated apple has descended and raises the long period of cultivation as the obstacle which effectually bars the way to knowledge of the original species. He cites the evidence of long cultivation and expresses the belief that the European forms now regarded as wild are probably hybrids escaped from cultivation. When the long period of cultivation is considered it does not seem strange that variation should have occurred, or that the number of forms should have become as great and as diverse as they are now known to be. To quote further from Professor Koch,[2]

"It appears to me that four or perhaps five species formed the foundation for our apples. It is possible, and to me seems probable, that these four species are so-called Darwinian species, that is to say, in the dissemination thru the long period of development the first formed constantly deviated and the species thus formed have by long propagation by seeds similarly continued to form others. These four or five ancestors are *Pyrus (Malus) pumila* Mill., *dasyphylla* Borkh., *sylvestris* Mill., and *prunifolia* Willd. Perhaps also *Pyrus spectabilis* should be included with our cultivated apples."

Of the forms named by Koch the first, *Pyrus pumila,* is the most common and has the widest distribution. Probably this was one of the forms and possibly the second, *dasyphylla,* was another upon which Linnaeus based his species *Pirus malus.* The following characterization of the different species is condensed from Koch's "Dendrologie."[3]

Pyrus (Malus) pumila is usually shrubby but sometimes becomes arborescent; leaves elliptical, tomentose beneath, styles glabrous not longer than the stamens; fruit umbilicate at base, pedicel short, stout. Commonly seen in thickets and most abundant in southeast Russia, Caucasus, Tartary, and the Altai Mountains. It grows as vigorously as *Malus sylvestris* but always remains low and is not long-lived; it is used as a stock for dwarfing standard orchard varieties. Under the name *Malus tartarica* the plant is common in gardens under several forms, as (1) The Johannis apple, distinguished by scant pubescence which is entirely confined to the top shoots of the current year and to the lower side of the young leaves, and by shining brown bark and brittle roots. The leaves taper in both directions and are longer than in other forms; the fruit is oblong, yellow, and is borne in clusters, ripening early in July. (2) The Splitt or Sweet apple, which has felt-like tomentum on young shoots and on the lower side of the shorter

[1]Koch, Karl. Dendrol. 1, 202. 1869.
[2]loc. cit., 202.
[3]loc. cit., 203-210.

leaves. This form is less wide-spreading and commonly forms a single trunk the bark of which is Indian red. The fruits are oblate and ripen later than those of the Johannis apple. The Splitt apple is the Doucin or Pomme de St. Jean of the French, the Doucin of Holland, the common Codlin of England. (3) The Corn or Jacob's Apple, very similar to the preceding, but less pubescent. Its fruits are globular, straw-colored, scentless, and subacid. (4) The Heck Apple (*Malus frutescens* Borkh. Handb. d. Forstbot. 2, 1267). This has wholly glabrous leaves and bushy form, is probably closely allied with *Malus sylvestris* and is possibly a hybrid between that species and a form of pumila. (5) The fig-apple (*Pyrus dioica* Mnch Verz. ansl. Bäume 87, t. 5, P. apétala Münchh. Hausv. 5, 247) which has neither petals nor stamens and produces a fruit without kernels.

The second species enumerated as one of the probable ancestors of the common apple is *Pyrus (Malus) dasyphylla* Borkh. Handb. d. Forstbot. 2, 1269 (1803). This, probably, is wild only in the orient. It is arborescent and the fruit ripens in September and October. Leaves broadly elliptical, variable in size, but usually 2 to 2½ inches wide and 3 to 4 inches long, tomentose beneath, styles longer than the stamens, hairy about the base; fruit umbilicate at base, stem short, stout, except that the common form is arborescent with less thorny and more horizontal branches. It closely resembles *Malus pumila*. It is possible that this species was developed thru long cultivation and then became wild. Some of the forms are said to have lobed leaves.

The third species is *Pyrus* (*Malus*) *sylvestris* Mill. gard. dict. 1 (1759) 7th ed. This is known as the smooth-leaved apple tree and probably came originally from southern Siberia and northern China. It is abundant in the wild state in Europe. Under cultivation it gives rise to numerous forms, some of which closely resemble *Malus pumila* while others more nearly resemble *Malus prunifolia*. The leaves are roundish, often cordate at base, sparsely pubescent above when young, glabrous below. Claw of the rose-colored petals very short; styles glabrous, not longer than the stamens; fruit umbilicate at base, stem short. It is possible that this species is only a wild form of the smooth-fruited summer apple which originally came thru cultivation from *Malus prunifolia*.

The fifth species is *Pyrus* (*Malus*) *prunifolia* Willd. phytogr. I. 8. (1794). The plum-leaved apple tree from northern China, Tartary, and southern Siberia. Arboreous; leaves long, lanceolate or elliptical, pubescent beneath only when young, petals white, styles hairy at base, fruit umbilicate at base, stem long, slender. There are numerous forms of this species. In some the fruits are quite small, in others more than an inch in diameter, while some forms bear fruits large enough and pleasant enough to give them rank as orchard varieties. In color the fruits are yellow, red, or striped; some light yellow fruits have a transparent appearance. The ice-apple of Russia, and the so-called Astrachan apple of Europe, which is also transparent, belong here. Most forms of *Malus prunifolia* have subacid fruits, but there are garden varieties that are sweet.

The fifth species which Professor Koch somewhat doubtfully included among the possible ancestors of the common apple is *Pyrus (Malus) spectabilis*,[1] a native of China.

"Leaves long-lanceolate, or elliptical, pubescent below when young; claw of the rose-red petals longer than the short calyx lobes, styles woolly at base, fruit scarcely umbilicate, imperfectly 10-celled. *Malus spectabilis* is closely related to *Malus prunifolia*, but is distinguished by the longer narrower leaves which are dull in color and more tardily glabrate beneath, the flowers also are larger and rose-red while those of *Malus prunifolia* are white."

[1]Aiton, William. Hort. Kew., ed. 1, 2, 175. 1789.

During the nineteenth century no species of Malus was so frequently mentioned or so highly praised by writers treating of ornamental trees as *Malus spectabilis*. It was widely disseminated and highly prized chiefly for the brilliant color of its unopened flower buds. Professor Koch states that it often is shrub-like, but commonly appears as a tree and sometimes attains considerable size. Loudon[1] cites several trees in England and France that grew to large size. "In the environs of London, at Spring Grove, a tree believed to be upwards of 50 years old, was, in 1834, 35 feet high; at Kenwood, 38 years planted, it is 34 feet high, the diameter of the trunk one foot seven inches, and of the head 28 feet." Several others mentioned range from 14 to 35 feet in height. There are various forms of this species some of which are named as varieties and are even given specific rank by some writers; such as *Malus sieboldi, Malus ringo, Malus kaido, Malus riversi,* and possibly also *Malus floribunda*. Some forms accredited to *Malus spectabilis* have leaves in some degree lobed and calyx lobes wholly or in part deciduous, thus more closely resembling either the Japanese species *toringo* or the Siberian species *baccata*. It seems most probable that these forms are hybrids between some form of *Malus spectabilis* and either *Malus toringo* or *Malus baccata* or both.

Professor Koch's extended researches into the origin of the numerous forms of Malus bring out clearly the hopelessness of the attempt to assign definite origin to the widely variant forms, because of the long period of cultivation and the undoubted free intermingling of original true species.

Varieties Used as Parents for Hybrids of Group 1

The 35 varieties used in Group 1 were:

Beach (Apple of Commerce)	Fanny	Melonen	Tolman
Ben Davis	Grimes	Oldenburg	Twenty Ounce
Black Ben Davis	Hall's No. 6	Oliver (Senator)	Willow
Borsdorf	Huntsman	Osimoe	Winesap
Collins	Ingram	Rome	Winter Rambo
Delicious	Isham	Shackleford	Wythe
Domine	Jefferis	Shockley	Yellow Transparent
Early Ripe	Jonathan	Springdale	
Fameuse	Longfield	Summer Pound Royal	
	Arkansas		

Place of origin is assigned, altho in some cases doubtfully, for 29 of these varieties, while 6 are recorded as of unknown origin. Six are Russian, 6 came from Arkansas, 3 from Pennsylvania, 3 from Missouri, and the remaining 11 from eleven states ranging from Rhode Island on the east to Iowa on the west. Six are summer varieties, 5 are fall varieties, and 24 are either early or late winter varieties. Only

[1]Loudon, J. C. Arboretum et Fruticetum Britannicum 2, 909. 1838.

two varieties, Isham and Tolman, are distinctly sweet, while all others are of varying degrees of acidity.

The sum of the matings for the different years was 159, but 10 of these appeared in more than one year so that the number of distinct combinations was 149; of these 55 failed entirely, leaving 94 combinations represented by greater or less numbers of successful pollinations.

The total number of flowers pollinated was 7,670, and of these 2,845 belonged to those combinations that failed entirely, which left 4,825 as the number of pollinations distributed among the 94 combinations that were in some degree successful. The aggregate of fruits harvested and described was 990.

Percentages of successful pollinations ranged from 2 percent for each of five combinations, in which 1 fruit was obtained for each 50 flowers pollinated, to 77.25 percent for a combination yielding 34 fruits from 44 flowers pollinated. The ratio of fruits to flowers pollinated was for all flowers, 1 to 7.7, or if only the combinations yielding fruits are considered, 1 to 4.87. For most combinations the percentages are low, more than a third of them have success percentages at or below 10 percent; 49 combinations have success percentages ranging between 10 percent and 50 percent, and for 11 combinations the percentages are above 50. The maximum referred to above is a combination of Rome X Collins with 34 fruits from 44 flowers pollinated, or 77.25 percent.

It is scarcely possible to point out specific causes accountable for the large proportion of combinations that failed entirely, or for the extremely low percentages of success that prevailed with many of the matings. Pollinations were made in the orchard and equal care was exercised in all. Of the several causes that operate to limit the numbers of flowers that develop fruits when undisturbed except by natural agencies, probably all were operative in one or more of the seasons except that of failure of pollen to reach stigmas. In all of the attempted combinations pollen was artificially applied to the stigmas of each flower, so that if failure followed it must be ascribed to some cause or causes other than the failure of pollen to reach the stigmas. Pollen may be defective, or of low vitality, or defect may rest with the stigmas, or some constitutional characteristic of either parent may inhibit fertilization, or still other causes may be active in determining results, but as in nature four-fifths of the flowers fail to form fruits it is reasonable to expect a considerable proportion of failures in flowers artificially pollinated.

Perhaps the best index to the degree of success attending pollination of apple flowers on trees in orchard is the ratio of fruits harvested to flowers pollinated. This ratio for the aggregate of pollinations in the seven years 1909 and 1911-1916 has already been stated to be 1 to 7.7, but there were very wide differences in seasons; thus the ratio for 1914 is 1 to 3.88, almost exactly double the ratio for the aggregates.

At the other extreme for attempted matings in orchard is the ratio 1 to 92.25 in 1916. This extreme needs explanation; it is based upon 8 combinations involving 369 flowers which yielded only 4 fruits. Five of the 8 combinations included 223 flowers and failed entirely. The 8 combinations were on a single Jonathan tree as the pistillate parent. The flowers emasculated were pollinated by pollen from 8 varieties; 50 flowers by Ben Davis gave 1 fruit; 49 flowers by Fameuse gave 1 fruit; 47 flowers by Longfield gave 2 fruits. These all show very low percentages of success. The other varieties used were Shockley on 47 flowers, Collins on 40 flowers, Jefferis on 48 flowers, Grimes on 45 flowers, and Oldenburg on 43 flowers; none of these produced fruits and, as the same lots of pollen used on other varieties gave a reasonable degree of success, it appears that the failures in five combinations and the near failure in the other three must be ascribed to some defect in the pistil-bearing parent rather than to the pollen used. Two years previously, Jonathan had given 22 percent of success with Grimes, 36 percent with Collins, 38 percent with Domine, and 8 percent with Arkansas; hence, the failure with Grimes and Collins in 1916 indicates a seasonal rather than a constitutional defect.

The tree bloomed abundantly and with one exception everything seemed to be as favorable as possible for success. The one exception was the age of the stigmas, or the length of the periods between emasculation and pollination. These periods varied from three days and nine hours for the flowers pollinated by Shockley and Collins to four days and eight hours for those pollinated by Oldenburg. That the periods were long was recognized, but cases of success with longer periods were matters of record and, as accumulation of data regarding behavior of stigmas of various ages were desired, pollination was performed. Had the stigmas been blackened or discolored they would have been discarded, of course, but they were not; neither did they have the aspect of stigmas in ideal condition, their appearance indicating a condition near enough to the life limit to raise the suspicion that failure would follow pollination. The doubt as to possible results could only be cleared by actual application of pollen; there seemed an equal chance that success would follow and that chance was taken. How near the life limit the time of pollination was, is seen in the fact that failure was not absolute in all matings; five failed entirely, but in the other three success ranging from 2 to 4.25 percent was recorded. Reviewing all the circumstances there is no hesitancy in assigning age of stigmas as the cause of the low ratio of fruits to flowers in these pollinations on Jonathan. The details of this case furnish another example of the objectionable inclusion of a special problem in a general scheme of breeding. Determination of the receptive period of stigmas demands the extremes, which, in fact, are the essentials of

the problem, and are reached only by taking chances that would not and should not be taken in pursuing a definite breeding project with apples or with any other plant.

Next to this extreme low ratio stands a ratio of 1 to 13.11 derived from the pollination of 2,151 flowers in 1913, which matured 164 fruits. In this year there were 49 combinations, 26 of which failed entirely, while 9 others gave success percentages below 5 percent. In this case, however, a definite trouble was accountable for the failures, or at least a very large percentage of them, altho the direct cause of the difficulty was never satisfactorily determined. Pollinations in 1913 were made under favorable conditions and there was every reason to expect a high percentage of success, but on removal of the paper sacks, about four weeks after pollination of the flowers, for the purpose of substituting cloth sacks on those clusters carrying fruits, it was discovered that flowers and leaves within many of the sacks were dying or were already dead and brown. This had not happened in preceding years, nor has it occurred since. Just when the injury occurred is not known, but from the fact that the dead leaves and flowers, altho brown, were still flexible and not dry and crisp, it seems certain that injury did not long precede examination. There was no evidence of the presence of insects or injurious fungi. Only one other possibility was suggested and that was that alternation of showers and sunshine had established relations between wet sacks and bright sunlight, thru which interior temperatures were raised to an injurious degree. Against this idea was the fact that, in a number of instances sacks containing injured twigs were in close proximity to others in which no injury occurred, both having the same exposure. In all seasons, in the interval between pollination and examination, there have been periods of alternating rain and sunshine, but only in this one instance did injury occur. That at some particular time there existed a combination of atmospheric conditions capable of inflicting the injuries observed seems a possibility, but the known facts are insufficient basis for any definite conclusion.

Other ratios of fruits to flowers pollinated were, for 1909, 1 to 5.72; for 1911, 1 to 7.8; for 1912, 1 to 10.66; and for 1915, 1 to 4.88. The rather wide range of ratios apparently was due to seasonal differences, altho in no year, except 1913, was there any particular circumstance observed that could be referred to as a cause of observed differences in ratios. In a number of instances the same combination was attempted in more than one year, giving reasonable success in one year and failing entirely the next. Violence of the cross can scarcely be appealed to as responsible for any of the failures because all crosses in this group are between varieties that presumably belong to the one species *Malus malus;* they are groups of plants that differ in purely varietal characters and the relationship is not distant.

On the other hand, it is conceivable and does not seem improbable that failure of some combinations may have been due to the other extreme of relationship; that is, so nearly related as to exhibit the self-sterility which has been demonstrated to be an attribute of most varieties in most seasons. The particular case in which this suspicion centers is the reciprocal combination of Domine and Winter Rambo, already referred to in connection with seasonal differences, but which may be considered here in greater detail. These varieties are very similar in appearance, altho Domine has the longer season and is less highly flavored; both have the habit of often being dull in color, and often the fruits of the two varieties are scarcely distinguishable.

Domine was pollinated by Winter Rambo as follows: in 1909, 49 flowers; in 1911, 50 flowers; in 1913, 60 flowers; and in 1915, 53 flowers; a total of 212 flowers, all of which failed to produce fruits. Complete failure in four seasons is fairly good ground for the belief that these two varieties, when crossed in this direction, are habitually sterile. For the reciprocal, Winter Rambo X Domine, pollinations were as follows; in 1909, 62 flowers; in each of the years 1911, 1913, and 1915, 47 flowers; a total of 203 flowers. The pollinations of 1909, 1911, and 1915, with a total of 156 flowers, failed entirely, giving almost as good ground for the suspicion of habitual sterility as existed in the case of the cross Domine X Winter Rambo, but suspicion of habitual sterility in crossing Winter Rambo X Domine is overthrown by the results in 1913 when, from 47 flowers pollinated, 6 mature fruits were harvested. This is only 12.75 percent successful for that year and less than 3 percent for the aggregate of flowers for all years, but it is sufficient to show that suspicion of habitual sterility in this cross is not well-founded and that under some conditions a certain degree of success is possible.

In what manner conditions of weather or of the trees differed in 1913 from the other years in which entire failure resulted is unknown, but that there was a difference in some particular seems indicated by the different results. To bear out the idea that the failures here recorded resulted from too close relationship between the two varieties, so close as to consider them strains of one variety and that the crossing amounted to selfing, the fruits produced should have been below normal in size, deficient in seeds, the seeds of low vitality and yielding only weak seedlings, but this is not in accordance with the facts. The 6 fruits were normal in size, ranged high in seed production, the seeds were viable and gave seedlings as vigorous as from most other crosses. The 6 fruits contained 69 plump seeds, or 11.5 to each apple, an average nearly 40 percent greater than the average of 8.27 seeds to the apple obtained from examination of 12,912 apples of large size representing 32 orchard varieties. Of the 69 seeds, 63, or 91.3 percent, germinated; the seedlings planted in orchard in the spring of 1916

numbered 56 and at the end of the season, in November, 50 were living and were rated as follows: good trees, 33; fair trees, 6; poor trees, 11. This is a larger proportion of good trees than is found in most other similar lots of hybrid seedlings. High content of viable seeds and vigor of seedlings is decidedly against the suggestion that the high percentage of failure in this cross may be due to sterility arising from close relationship of the varieties paired. In spite of the close resemblance of the fruits, the varieties Winter Rambo and Domine must be considered as distinct varieties, and the cause of entire failure to cross in one direction and partial failure to cross in the other direction may not properly be ascribed to close relationship, but must rest in some factor or factors at present unknown.

Of the varieties mated, Oldenburg has the highest ratio between fruits matured and flowers pollinated; 584 flowers pollinated gave 222 fruits, or a ratio of 1 to 2.63; this represents 10 combinations, one of which, that with Winter Rambo, failed entirely. The percentages of success for the other 9 combinations ranged from 6.12 percent for Rome to 76.5 percent for Hall's No. 6. Next to Oldenburg in accomplishment stands Rome, with a record of 554 pollinations yielding 193 fruits, a ratio of 1 to 2.86. There were 12 combinations represented with percentages of success ranging from 8.1 percent for Isham to 77.25 percent for Collins. Other varieties with high ratios were Wythe, 1 to 3.4; Longfield, 1 to 4.6; Grimes, 1 to 5.6; Shackleford, 1 to 6.1; and Yellow Transparent, 1 to 6.6. The varieties mentioned are those having the best records; certain other varieties took places at the other extreme, either with records of entire failure or with very low percentages of success; thus Arkansas with 273 flowers pollinated, in numbers from 32 to 96, by five different pollen plants, yielded no fruits, and Winesap with 247 pollinations distributed among seven pollen plants also failed to yield fruits. Low percentages of success are recorded for Beach, 1.13 percent; Fanny, 2 percent; Isham, 4.5 percent; and Willow, 4.6 percent. Remaining varieties of the list range intermediate between those mentioned in percentages of successful pollinations.

Seed Production in Hybrid Fruits in Group 1

Seed production of the hybrid fruits in this group of orchard varieties X orchard varieties is rather low. The 990 fruits produced 6,989 seeds that were saved for planting; this gives an average of 7.05 seeds to each fruit. A fraction above 11 percent must be added to this average to equal the average obtained from count of seeds in 21,412 apples that had developed from flowers pollinated by natural agencies, which is 7.85 seeds to each apple. The apples from open pollinated flowers contained seeds in numbers ranging from 0 to 27, while the fruits from flowers artificially pollinated had a seed range

from 2 to 15. Only 3 of the 94 combinations had seed averages equal to or exceeding the full complement of a normal apple, namely, 10 seeds. Six combinations had averages of 9 or above, but less than 10; 60 combinations had averages of 6 or above but less than 9; and 25 had averages of less than 6. The three combinations having averages above 10 are Winter Rambo X Domine—6 fruits from pollination of 47 flowers contained 69 seeds, an average of 11.5; Winter Rambo X Jonathan—7 fruits from 47 flowers pollinated contained 73 seeds, an average of 10.42; and Huntsman X Osimoe, in which 49 flowers pollinated gave 5 fruits containing 51 seeds, an average of 10.2. The minimum seed production is found in two combinations, Ben Davis X Twenty Ounce, in which pollination of 50 flowers gave 1 fruit yielding 2 seeds, and Jonathan X Fameuse, in which 49 flowers pollinated gave 1 fruit, also containing only 2 seeds.

Table 2 gives the distribution of seeds in the hybrid fruits of the group orchard varieties X orchard varieties. It will be observed that the aggregate of fruits included in the tabulation was 977, while the aggregate of fruits produced in the group was 990. This difference of 13 represents those fruits for which the seed record was wanting or incomplete. They were fruits whose seeds had been wholly or partially destroyed by insects and for this reason were omitted from the tabulation of seed distribution. There were six different matings that had one such fruit in each, two matings that had two each, and one mating of Grimes X Shackleford that had three. The infestation was in all cases by second-brood larvae of the codling moth; fruits were in large measure protected by the cheesecloth sacks with which they were covered, but infestation, particularly where two fruits develop in the same sack, is very often possible and occasionally occurs.

Seeds Planted in Group 1

There is, in many cases, some difference between the total seeds saved from hybrid fruits and the number planted. The season of maturity of hybrid fruits has extended, in the several years, from July 22 for Yellow Transparent to November 11 for Wythe and Collins. As fruits reach maturity they are picked, described, the seeds extracted, and such as appear sound are placed in envelops which are classified and stored in a vault where they remain until time for planting. In the earlier years of the work it was the custom to stratify the seeds in sand late in the fall, bury the receptacles in a pit for the winter, and then plant in the spring. This plan did not prove to be wholly satisfactory. Apple seeds germinate at very low temperatures. In some seasons, warm periods in late February or early March will start the germinating process long before it is thought possible to plant and care for the seeds. In 1910, and again in 1912,

TABLE 2.—DISTRIBUTION OF SEEDS IN HYBRID FRUITS OF GROUP 1, ORCHARD VARIETIES X ORCHARD VARIETIES

Variety	Number of parental combinations	Number of fruits	Number of seeds	Average number of seeds to 1 fruit	Seeds to each fruit															
					0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Beach	1	1	10	10.00	...	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...
2 Ben Davis	6	27	134	4.96	...	1	2	2	4	8	5	3	2	...	...	...	...	...	...	...
3 Black Ben Davis	3	16	69	4.31	...	1	2	2	5	3		2	...	1	...	...	...	...	...	...
4 Borsdorf	1	2	19	9.50	...	...	...	...	...	...	...	...	...	1	1	...	...	...	...	...
5 Collins	1	11	71	6.45	...	...	...	...	2	1	3	3	...	1	1	...	...	...	...	...
6 Domine	4	25	216	8.64	...	...	1	1	...	...	2	1	6	4	5	3	1	1	...	...
7 Fameuse	5	45	352	7.82	...	...	...	1	2	2	2	9	13	8	8	...	...	...	...	...
8 Fanny	1	1	5	5.00	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
9 Grimes	3	23	134	5.82	...	2	3	...	2	3	2	3	3	4	1	...	...	...	...	...
10 Hall's No. 6	2	3	20	6.66	...	...	...	...	...	...	1	2	...	...	...	...	...	...	...	...
11 Huntsman	1	5	51	10.20	...	...	...	...	...	...	1	1	...	...	...	1	...	1	1	...
12 Isham	2	11	68	6.18	...	...	...	...	3	1	2	2	2	1	...	...	...	...	...	...
13 Jonathan	7	55	340	6.18	...	...	1	...	6	11	16	9	8	4	...	...	...	...	...	...
14 Longfield	2	21	178	8.47	...	...	...	...	...	...	1	4	4	8	4	...	...	...	...	...
15 Oldenburg	9	219	1 450	6.62	...	...	4	12	23	26	39	30	39	32	14	...	...	...	...	...
16 Osimoe	5	39	323	8.28	...	...	...	...	1	1	5	6	5	8	13	...	...	...	...	...
17 Rome	11	186	1 298	6.97	...	1	4	6	14	21	30	33	28	27	14	5	2	1	...	...
18 Shackleford	6	64	488	7.60	...	1	...	3	...	3	9	12	16	10	8	...	...	1	1	...
19 Springdale	1	3	11	3.66	...	...	1	1	...	...	1	...	...	...	...	...	...	...	...	...
20 Summer P. Royal	1	8	72	9.00	...	...	...	...	...	...	...	1	1	3	3	...	...	...	...	...
21 Tolman	6	43	295	6.86	...	2	2	2	4	...	8	5	5	8	6	...	1	...	...	...
22 Twenty Ounce	2	3	24	8.00	...	...	...	...	...	...	...	...	3	...	...	...	...	...	...	...
23 Willow	2	10	76	7.60	...	...	...	...	...	1	2	1	3	2	1	...	...	...	...	...
24 Winter Rambo	2	13	142	10.92	...	...	...	...	...	...	...	...	1	2	2	4	2	1	...	1
25 Wythe	7	102	813	7.97	...	3	1	1	2	2	12	14	25	20	16	1	1	2	2	...
26 Yellow Transparent	3	41	330	8.04	...	...	...	...	...	2	4	10	11	8	2	2	2	...	...	...
Total	94	977	6 989		0	11	21	31	68	86	145	151	175	152	100	16	9	7	4	1

this early activity occurred. Altho the conditions were carefully studied, judgment was in error as to the time for lifting the containers, germination has commenced, and some losses were experienced in removal and planting.

For the past three seasons planting has been done the first week in December. Dirt bands made of veneer cut to fold 2½ inches square and 5 inches deep are arranged in greenhouse flats of proper dimensions to hold eighty-four bands; these are filled with good garden soil and a single seed planted in each band. Record of planting is kept on sheets ruled in squares corresponding to the bands in each numbered flat. When planting is completed the flats are stacked in a pit excavated for the purpose. This pit is of proper dimensions to hold two ranks, four flats deep and long enough to accommodate whatever number is in use. Each flat is accurately placed so that no cracks are left that would allow entrance for mice, and the whole is covered with sheet metal to prevent flooding in case of heavy rains. When the stack is complete it is covered with earth which is rounded above and so shaped as to provide perfect drainage. In early spring, usually the third week in March, the flats are removed to cold frames, arranged in numerical order, and a 4½-inch pot label bearing the proper number is placed in each band. The date of appearance of each seedling is recorded on forms prepared for the purpose. In May the bands containing seedlings are placed, 1 foot apart, in nursery rows.

This method of handling several thousand seeds and preserving the identity of each has proved very satisfactory. Assuming December 6 as the date of beginning planting (this was the actual date in 1915 and again in 1916), the dry storage period of seeds in envelops may vary between 25 days for seeds from fruits picked on the latest picking date November 11 to 138 days for seeds from fruits picked July 22. During this period of storage some seeds may develop defects that were not apparent, or were overlooked at time of extraction. Occasionally a seed is injured in cutting the fruit at the time seeds are extracted, or a seed that from external appearance is normal and viable may have an embryo so defective that the seed shrivels upon drying. All seeds that appeared to be in any way defective were discarded at planting time.

Seed Losses

In this group of hybrids (orchard varieties X orchard varieties) the aggregate of seeds saved was 6,989. The number planted was 6,440—hence 549 represents the number of seeds found defective and discarded during the planting. This is nearly 8 percent of the aggregate of seeds saved. In 51 of the 94 matings represented, there were no losses, the number planted was in each case equal to the number saved. The losses, then, were distributed among 43 matings and

ranged from 1 in each of 8 matings to 109 in the cross Shackleford X Grimes; in this case a loss of nearly 44 percent. For the large majority of combinations the losses of seeds between extraction and planting are very small, but in a few cases they are large enough to attract notice. Examination of seeds discarded as imperfect indicates that they represent a stage of development intermediate between full and perfect development and that stage frequently observed at the time of extracting seeds from fruits, in which the testa appears fully formed, but empty, there being no development of embryo.

Percentages of Germination Vary Widely

The germination considered included only those cases where seedlings appeared at the ground surface. Doubtless some weak seeds protruded roots or even started development of the caulicle, but did not have sufficient vitality to reach the surface; such cases were not included in the germination record. Of the 6,440 seeds planted, 4,007, or 62.22 percent, were recorded as having germinated. The combinations were between parent plants that are quite diverse in character, and it is only natural that there should be wide range in percentages of germination. The minimum percentage was 3.13 in the cross Osimoe X Winter Rambo; of 32 seeds planted only one germinated. Next above this was the cross Yellow Transparent X Oldenburg, in which 14 fruits gave 102 seeds, of which number only 7, or 6.86 percent, germinated. Other combinations showing low percentages of germination were Twenty Ounce X Oldenburg, in which 2 of 15 seeds, or 12.5 percent, germinated, and Yellow Transparent X Domine, in which 37 of 220 seeds planted, or 16.82 percent, germinated. At the other end of the line were 6 combinations in which 100 percent germination was recorded, but these involve relatively small numbers of seeds; two of the combinations had 7 each, 2 had 8 each, 1 had 10, and 1 had 20. Eight combinations had percentages of germination between 90 and 100, representing 480 seeds; 40 combinations with 2,495 seeds had percentages of germination between 60 and 90; percentages for the remaining combinations ranged down to about 20 percent. Compared with the standards of germination demanded for seeds of cereals, the percentages obtained for seeds of this group of apples were quite low; but for apple seeds representing so large a variety of parental combinations and developed in fruits resulting from artificial pollinations, the general average of 62.22 percent was perhaps as high as could be expected.

Hybrid Seedlings Now Living

When the census of seedlings resulting from the pollinations made in the group under consideration was taken in November, 1916, there were living 2,952 seedlings 1 to 7 years of age. These represent 45.98

percent of the aggregate of seeds planted, or 73.67 percent of the seeds germinated. To state the results in a different way, there was one tree living for each 1.6 flowers pollinated, or one tree for every 2.18 seeds planted, or one tree for every 1.35 seeds germinated. These computations are from aggregates, but of course the divisions of the group for the different years are scarcely comparable because of the age difference. Seedlings from crosses of 1909 have weak seedlings more completely eliminated and have been subject to the attacks of disease for a longer period; hence the numerical relation between seeds germinated and seedlings living may naturally be expected to be quite

TABLE 3.—NUMERICAL RELATION OF TREES LIVING TO SEEDS GERMINATED IN GROUP 1, ORCHARD VARIETIES X ORCHARD VARIETIES, WITH PERCENTAGES AND AGES OF TREES

Year	Seeds germinated	Number of trees living	Percentage of trees living	Age of trees, *yrs.*
1909	546	424	77.65	7
1911	732	526	71.85	5
1912	365	218	59.72	4
1913	898	660	73.49	3
1914	1 041	726	68.04	2
1915	425	398	93.64	1

different from that of the one-year-old lot resulting from crosses of 1915. The relation of trees living to seeds germinated may be shown most accurately by years in Table 3. Whether the percentages given in the tabulation are high or low depends somewhat upon the point of view, but it is believed that, when the nature of the plants is considered, the percentages of living trees are approximately what may be reasonably expected. There are differences between the years and it appears that the percentage for 1909 is higher than that for any other year, when the age of the trees is considered. For the year 1909, 546 seeds germinated out of 1,643 planted, or 33.23 percent. The seedlings were grown in the nursery three years before planting in the orchard, during which period 42 trees died; this is 7.69 percent of the number that germinated. In the spring of 1913 the survivors, 504 in number, were planted in the orchard, and during the four years since there has been a loss of 80 trees, or 15.87 percent of the number planted. This brings the total loss from time of germination to 122 trees, or 22.34 percent of the number germinated. The loss of trees in the orchard was due almost entirely to attacks of blight; probably some trees were inherently weak and particularly susceptible to the disease.

From the crosses of 1915 there are 398 seedlings living of the original 425; this is 93.64 percent, but there will be losses in each of the succeeding years and it may be questioned whether or not the percentage at the end of the seventh year will exceed that for the

seedlings of 1909. The seedlings of all other years now have percentages of living trees less than that shown for the seven-year-old seedlings and during the two to four years before they attain the age of seven they will sustain losses that must increase the existing difference.

In each of the six years there were wide differences in the behavior of different parental combinations. Some combinations stood much lower than others both in percentages of seeds germinated and in percentages of trees living; these combinations, as a rule, produced trees that were manifestly inferior to those of other combinations, and the whole performance seems to indicate that these particular combinations of parents are undesirable. There was nothing in appearance of varieties, or in anatomical structure of floral parts, to suggest causes of unsatisfactory behavior, and it must be concluded that these causes lie in factors of constitution that have descended from the unknown ancestors.

Of the 35 orchard varieties represented in the 149 combinations attempted in this group of orchard varieties X orchard varieties, 31 have been used as pistillate parents, 26 of which bore fruit. Twenty-eight varieties have been used as pollen-bearing parents. Four varieties were used only on the female side, and six only on the male side. There were 55 attempted matings that failed entirely and 6 of the varieties used in these attempted combinations do not appear in combinations that produced fruits. Thus 94 matings that yielded fruits involve 29 varieties. Most of the 55 matings that failed entirely involved flowers in such small numbers that the failures cannot be regarded as an index of the possibilities of the respective matings. They were made in the greenhouse on potted trees flowering for the first time and each producing only one or two clusters with only two, or, at the most, three emasculations in each cluster.

Individual Records in Group 1

Results from the 94 matings yielding fruits are so various in ratios of fruits to flowers pollinated, in seed production of fruits, and in numbers of living seedlings that consideration in groups is not desirable; perhaps the best that can be done is to select a few representative varieties used as mothers and give for each, in tabular form, the results obtained as mated with various pollen producers. Examine first Oldenburg in its relation to nine different pollen plants as in Table 4.

Percentages of successful pollinations range from 5.61 for the cross Oldenburg X Domine, and 6.12 for the cross Oldenburg X Rome, to 74.47 for the cross Oldenburg X Hall's No. 6, and 72.92 for the cross Oldenburg X Shackleford. While it required the pollination of only 1.34 flowers for the production of one fruit in the cross Oldenburg X Hall's No. 6, it required pollination of 17.83 flowers to produce

TABLE 4.—RECORD OF OLDENBURG POLLINATED BY NINE OTHER VARIETIES

Male parent	Year	Number of flowers pollinated	Number of fruits picked	Percentage of success	Number of seeds			Percentage germinated	Seedlings living Nov., 1916	
					Saved	Planted	Germinated		Number	Age, *yrs.*
1 Domine.....	1909	107	6	5.61	26	26	10	38.46	8	7
2 Twenty Oz....	1909	49	26	53.06	148	148	59	39.86	52	7
3 Yellow Tr....	1909	93	43	46.24	285	285	93	32.63	84	7
4 Hall's No. 6...	1909	47	35	74.47	241	241	113	46.89	93	7
5 Shackleford...	1911	48	35	72.92	268	220	152	69.09	135	5
6 Summer P. R.	1912	49	8	16.33	63	60	42	70.00	25	4
7 Rome.....	1912	49	3	6.12	22	21	9	42.86	5	4
8 Fanny.....	1913	48	31	64.58	202	191	157	82.20	118	3
9 Ben Davis....	1913	46	32	69.56	195	163	134	82.21	116	3

one fruit in the cross Oldenburg X Domine and 16.33 flowers for one fruit in the cross Oldenburg X Rome. The extremes are sufficiently remote to indicate rather wide differences in the crosses cited. The cross Oldenburg X Domine which has the lowest percentage of successful pollinations is also lowest in seed production; the six fruits yielded 26 seeds, an average of 4.33 to each fruit. The highest average seed production falls to the cross Oldenburg X Summer Pound Royal; this average is 7.87 seeds to each fruit, very little above the average previously given for open pollinated fruits. No one of the crosses has high seed production and for most it may be rated as low. In germination of seeds, five of the crosses have percentages below 50, the other four range from 69.09 percent to 82.21 percent. The average percentage for all of the crosses is 56.75, which is somewhat below the expectation for this group of crosses.

In persistence of the seedlings there were considerable differences between the crosses. The cross with Rome ranked lowest with 5 of the original 9 seedlings persisting at four years of age; this is 55.5 percent of the germinations; the next higher percentage is 59.52 for the cross with Summer Pound Royal; here there were 42 germinations, from which 25 seedlings were living at the end of the fourth year. Crosses of 1913 with Fanny and Ben Davis stand next; in these crosses the numbers involved were somewhat larger, and after two years in nursery and one year in orchard the percentages of living seedlings are 75.14 percent for the cross with Fanny, and 86.56 percent for the cross with Ben Davis. Next, with seedlings five years old is the cross with Shackleford which, from 152 seeds germinated, now has 135 seedlings living, or 88.88 percent. The remaining four crosses of 1909 have seedlings now seven years old and well established in orchard; the percentages of seeds germinated that are now represented by living seedlings are as follows: cross Oldenburg X Domine, 80 percent; Oldenburg X Hall's No. 6, 82.3 percent; Oldenburg X Twenty Ounce, 88.13 percent; and Oldenburg X Yellow Transparent, 90.32 percent. For this Oldenburg group of crosses the percentages of seedlings that have lived to become established in orchard are reasonably satisfactory.

As a second illustration of performance in crossing, those combinations in which Rome appears as the pistillate parent may be tabulated as for the Oldenburg group (Table 5). Twelve varieties were used as pollenizers and the crosses were made in five successive years. The percentages of successful pollinations range, in this group, from 8.11 percent for the mating with Isham in which pollination of 37 flowers yielded but 3 fruits, to 77.28 percent for the mating with Collins in which 34 fruits were produced from 44 flowers pollinated. This last percentage is the highest obtained from any pair of orchard varieties. Next to the cross Rome X Collins stands Rome X Osimoe

TABLE 5.—RECORD OF ROME POLLINATED BY TWELVE OTHER VARIETIES

Male parent	Year	Number of flowers pollinated	Number of fruits picked	Percentage of success	Number of seeds			Percentage germinated	Seedlings living Nov., 1916	
					Saved	Planted	Germinated		Number	Age, *yrs.*
1 Winter Rambo....	1911	50	20	40.00	153	150	66	44.00	33	5
2 Ben Davis...	1912	49	8	16.32	49	36	31	86.11	26	4
3 Arkansas....	1912	48	9	18.75	44	31	18	58.06	4	4
4 Grimes.....	1912	46	19	41.30	122	70	57	81.43	28	4
5 Isham.....	1913	37	3	8.11	12	12	3	25.00	1	3
6 Fanny.....	1913	45	5	11.11	24	24	14	58.33	5	3
7 Osimoe.....	1914	50	37	74.00	231	223	168	75.34	133	2
8 Collins.....	1914	44	34	77.28	227	188	135	71.81	102	2
9 Domine.....	1914	50	18	36.00	122	122	70	57.38	32	2
10 Fameuse....	1914	44	8	18.18	59	59	48	81.36	25	2
11 Jonathan....	1914	45	16	35.56	121	121	106	84.30	75	2
12 Shackleford..	1915	46	16	34.78	134	132	108	81.82	103	1

with a percentage of 74; other crosses range far below the high percentages given and the general average for all matings with Rome is only 34.83 percent, as compared with 40.85 percent for the group of Oldenburg crosses. The 12 Rome crosses exceed the 9 Oldenburg crosses in numbers of flowers pollinated by 18, but the Oldenburg group has 26 more fruits than has the Rome group. In the Oldenburg group 1 fruit was obtained for each 2.44 flowers pollinated, while in the Rome group 2.87 flowers were pollinated for each fruit picked.

The average seed production in this group of Rome crosses is 6.72 seeds to each fruit; the range is from 4 seeds to each fruit for Rome X Isham to 8.37 seeds to each fruit for Rome X Shackleford, the maximum more than twice the minimum. The loss of seeds between the time when taken from the fruit and planting was almost exactly 10 percent, distributed among 7 of the crosses and ranging from 1.5 percent for the cross Rome X Shackleford to 42.62 percent for the cross Rome X Grimes. For 5 of the crosses there were no losses of seed. Germination in this group of crosses is good in relation to germination in other groups; for 5 of the 12 crosses the degree of success is above 80 percent and only 1 rates as very low; that is, Rome X Isham, in which cross only 3 of the 12 seeds from 3 fruits germinated. The maximum germination is recorded for the cross Rome X Ben Davis, in which 31 of the 36 seeds planted germinated. The percentage for all crosses is 70.54, which, compared with the 56.75 percent for the Oldenburg crosses, shows a distinctly better performance on the part of the Rome group of crosses.

As regards persistence of seedlings this group of Rome crosses does not compare favorably with the Oldenburg crosses. The losses for the Oldenburg group up to this time amount to 17.3 percent, while for the Rome group the losses have reached 31.19 percent. The actual difference between the groups in this regard is even greater than is shown by the loss percentages because of the greater age of the Oldenburg seedlings, more than one-third of which are seven years old, and the group contains no one-year-old seedlings. The maximum age of Rome seedlings is five years and that age is represented only by the cross Rome X Winter Rambo which has 33 trees, and, further, in the cross Rome X Shackleford the seedlings are only one year old; the percentage of trees living in this cross is 95.37, but by the time they attain three years, which is the minimum age in the Oldenburg group, it is probable that this high percentage will be much reduced.

Comparisons between the different crosses in this Rome group are not satisfactory because of differences in age of living seedlings, differences in numbers of fruits and seeds, and the additional fact that only the results of one season are recorded for each cross. Any one of the crosses tabulated, if repeated in another season might, and probably would, give quite different results in percentages of success-

ful pollinations, seed production, and seed germination, these different results being due to some slight seasonal difference in the vigor of one or the other of the plants mated. This seasonal variation is something affecting all varieties, but all varieties are not affected in the same way in any particular season.

Various causes may act to produce the differences, which, altho often intangible or unobserved, are sufficient to impair the results or entirely inhibit successful crossing between two individuals. Slight differences in the situations occupied by two trees which it is proposed to cross and which subject one to different air currents, water supply, or soil fertility from the other, may react to modify the development of stamens and pistils and so diminish the vitality of parts that they are incapable of performing proper functions. Differences in performance in fruit production the preceding year may enhance the vitality of one and diminish that of the other even tho both bloom abundantly and appear normal. It has been frequently observed that an individual producing abundant, perfect pollen in one season may, the following season, have pollen deficient in quantity and with an increased proportion of defective grains; so too, the vigor of pistils as evidenced by position, robust structure, and evident receptiveness may have these qualities in less marked degree in another year. Because of a slight difference in degree of advancement of buds in spring, a frost may, without killing, injure those of one of a proposed pair, leaving those of the other uninjured. These are only a part of the causes accountable for differences in the results obtained with particular crosses, but that seasonal differences are of common occurrence is well understood by those who have practiced crossing apple varieties, and the existence of these differences suggests caution in basing judgment regarding the desirability of any particular cross upon the performance of a single season.

As further illustration of the behavior of particular crosses between orchard varieties, the results obtained with Wythe and Shackleford as mother plants are tabulated (Table 6). For Wythe there are seven crosses representing six combinations; the 1913 cross with Rome being repeated in 1915; these crosses are distributed in three years and the resulting seedlings are now one, three, and five years old. For Shackleford (Table 7) there are also seven crosses representing six combinations; the 1909 cross with Oldenburg being repeated in 1911; these crosses are distributed over five years and the various lots of seedlings are two to six years old.

These two groups of crosses show the same irregularities found in the Oldenburg and Rome groups. Percentages of successful pollinations range for the Wythe group, from 14.28 for the 1913 cross with Rome, to 52.08 for the 1915 cross with Collins; none of them are high, the average percentage for all being 29.39. For the Shackle-

TABLE 6.—RECORD OF WYTHE POLLINATED BY SIX OTHER VARIETIES

Male parent	Year	Number of flowers pollinated	Number of fruits picked	Percentage of success	Number of seeds			Percentage germinated	Seedlings living Nov., 1916	
					Saved	Planted	Germinated		Number	Age, *yrs.*
1 Winter Rambo....	1911	50	16	32.00	135	126	93	73.81	73	5
2 Borsdorf.....	1911	50	16	32.00	154	151	114	75.41	67	5
3 Willow.....	1913	50	19	38.00	162	160	151	94.38	108	3
4 Rome.....	1913	49	7	14.28	49	48	47	97.91	28	3
5 Rome.....	1915	50	9	18.00	62	62	58	93.54	50	1
6 Collins.....	1915	48	25	52.08	192	191	149	78.01	136	1
7 Longfield.....	1915	50	10	20.00	65	65	44	67.69	43	1

TABLE 7.—RECORD OF SHACKLEFORD POLLINATED BY SEVEN OTHER VARIETIES

Male parent	Year	Number of flowers pollinated	Number of fruits picked	Percentage of success	Number of seeds			Percentage germinated	Seedlings living Nov., 1916	
					Saved	Planted	Germinated		Number	Age, *yrs.*
1 Oldenburg....	1909	50	10	20.00	95	95	47	49.47	41	7
2 Oldenburg....	1911	50	5	10.00	39	39	18	46.15	15	5
3 Isham.....	1911	49	5	10.20	23	18	13	72.22	9	5
4 Grimes.....	1912	48	31	64.58	249	140	84	60.00	50	4
5 Jonathan.....	1913	50	1	2.00	5	5	3	60.00	1	3
6 Domine.....	1913	47	1	2.13	3	3	2	66.66	2	3
7 Fameuse.....	1914	48	11	22.92	74	74	54	72.97	46	2

ford group the range of percentages of successful pollinations is still wider, the minimum being 2.00 for the cross with Jonathan, and the maximum 64.58 for the cross with Grimes; six of the seven crosses must be regarded as having very low degrees of success, and the average for the group is only 18.71 percent. Altho the maximum of successful pollinations is attained in the cross Shackleford X Grimes of the Shackleford group, the average for all crosses of the group is considerably below the average for crosses of the Wythe group—18.71 for the Shackleford group and 29.39 for the Wythe group. In the matter of seed germination the difference between the two groups is still greater; the percentage of seeds germinated in the Wythe group is 81.69 and only 59.09 in the Shackleford group. Persistence of seedlings is not materially different in the two groups. The percentages of seedlings living in November, 1916, were 74.20 for the Shackleford group and 76.98 for the Wythe group, an apparent slight advantage for the Wythe group, but bearing in mind that about 45 percent of the Wythe seedlings were only one year old and that only about 28 percent of the Shackleford seedlings were in the youngest lot, and these two years old, it is perhaps best to assume the groups to be equal in persistence of seedlings.

GROUP 2: ORCHARD VARIETIES X CRAB-LIKE FORMS OF MALUS

There are gathered together in this group all attempts to hybridize in which the pistillate parent is an orchard variety and the pollen-bearing parent a crab, or a crab-like form of some species of Malus. Many of the matings have been between extremes of Malus forms; some of the pollen plants are shrubs rather than trees, and some have fruits no larger than peas; while in some the leaves are variously lobed, and in others, glabrous. In some the calyx lobes are regularly deciduous; in some the lobes are persistent and in still others the individual carries fruits, some of which have the lobes deciduous while on other fruits they persist. There are also wide differences in numbers of carpels in the ovary, in fruit and foliage coloring, in length of pedicels, in manner in which fruits are borne, in season of maturity of fruits, and in numbers of petals, stamens, and styles.

Hybridizing Work of Dr. Saunders and Others

Of the breeding possibilities of most of these diverse forms little appears to be known. The statement that they hybridize readily is common, but there are few accounts of systematic attempts to breed together particular species or forms, and these involve only a small number of the many kinds available. In 1888 Professor John Craig, then at the Iowa Agricultural College, hybridized *Malus toringo* by

pollen of Wythe, and *Malus ringo* with pollen of Oldenburg.[1] In 1896 report on these hybrids was made by Professors J. L. Budd and N. E. Hansen[2] as follows:

"The hybrids of *Pyrus Toringo* and *Pyrus Ringo* crossed with Wythe and Duchess pollen have fruited, but the fruit has little if any value. *Pyrus Toringo* pollinated with Duchess produced seedlings with upright habit and much modified foliage. The fruit resembles Duchess in shape and striping, but is not larger than a small crab and ripens earlier than either parent. This cross is a violent one, as the *Pyrus Toringo* is a bush species from east Europe with small cut leaves and fruit not larger than a marrowfat pea. Our experience and that of others in Europe and America lead to the belief that such violent crosses rarely if ever give valuable results. Our most pronounced successes have been with nearly allied varieties or species."

In 1894 Dr. William Saunders, then Director of the Central Experimental Farm, Ottawa, Canada, began hybridizing *Malus baccata* and the best orchard varieties grown in Ontario. This work was undertaken with a view to the production of varieties of sufficient hardiness to resist the climatic extremes of the northwestern plains provinces of Canada. Seedlings of *Malus baccata* grown from seeds obtained from the Royal Botanic Garden at St. Petersburg, Russia, had, thru a test of several years, proved hardy at plains stations, and flowers of these, as mother plants, were pollinated with pollen from the selected varieties.

Dr. Saunders in 1911 gives an account of the work in a bulletin[3] entitled, "Progress in the Breeding of Hardy Apples for the Canadian Northwest," and from this the following quotations are of interest here:

"This work was begun in 1894 and has since been continued along several different lines. The seeds obtained from the first crosses were sown in the autumn of that year and germinated in the following spring, producing, in all, about 160 young trees. . . . In 1899 thirty-six of the cross-bred apples first produced and grown at Ottawa fruited, and five of them were of such size and quality as to justify their being propagated for more general test. The cross-bred sorts grafted on roots of seedlings of *Pyrus baccata* have produced trees which, so far as they have been tried, seem to be quite as hardy as the wild form of baccata. There seems every reason to expect that they will prove generally hardy thruout the northwestern country.

"In 1896 a series of crosses was begun on another sort of wild crab, known as *Pyrus prunifolia*. . . . Its hardiness in the Northwest has also been established by a test covering a number of years on both of the experimental farms at Brandon and Indian Head. The first crosses with this species were made in 1896 and since then many new sorts have thus been originated. . . .

"Another line of work in producing new apples was begun in 1902, in crossing *Pyrus Malus*, the wild apple of Europe, with some of the best Canadian sorts. This fruit is about an inch in diameter to start with, and of fair quality. A hardy form of this tree has been secured which has stood several winters at

[1]Iowa Agr. Exp. Sta. Bul. 14, 189. 1891.
[2]Iowa Agr. Exp. Sta. Bul. 32, 498. 1896.
[3]Canad. Cent. Exp. Farm Bul., 68. 1911.

Brandon and Indian Head without injury, and with this additional crosses have been made. . . . Many of the best of the crosses produced on *P. baccata* and *P. prunifolia* have been recrossed, thus introducing a second quota of the blood of the larger apple with the hope of obtaining fruits of larger size and higher quality. Regarding these there is as yet not much proof that they are sufficiently hardy to endure the climate of the Northwest; this can only be fully determined by further experiment. Two varieties of these crosses of Ontario and Spy have been tested for several years at Indian Head, but have not yet fruited. Thus far they have been fairly hardy."

Dr. Saunders gives brief descriptions of seventeen named hybrids derived from pollinations of *Malus baccata* by nine different orchard varieties; these fruits exhibit various color combinations and average 1.5 inches in diameter. A further list of thirteen named *baccata* hybrids is given, but the fruits are said to be less desirable than those of the first list. Hybrids between *Malus prunifolia* and four orchard varieties are represented in a list of ten named varieties, fruits of which range from 1.5 inches to a little more than 2 inches in diameter, with an average diameter of 1.82 inches. Trees of the *baccata* hybrids were distributed to settlers in various parts of the western provinces in 1902 and 1903.

At the close of the bulletin Dr. Saunders sums up as follows:

"Since the first seeds of *Pyrus baccata* were obtained from the Royal Botanic Gardens, St. Petersburg, Russia, in 1887, twenty-four years have passed. As shown by the facts submitted in this bulletin, during this time a large number of experiments have been carried on with varying success, and the indications are that, by persevering along the lines laid down, in a very few years a number of varieties of apples will be available possessing that hardiness, size, and quality which will commend them to the settlers in all those portions of the northern country where ordinary apples under average conditions cannot be grown. The success thus far achieved is most encouraging and doubtless greater triumphs in the future will reward persistent efforts."

The work thus far done at the Illinois Station is only the beginning of an attempt to ascertain the possibilities of the various forms of Malus as breeding material. Flowers of certain of the common orchard varieties have been pollinated with pollen from as many diverse forms as chanced to be available, in order to test the behavior of each in its relation to the particular variety. Thus flowers of Grimes have been pollinated with pollen of 16 different Malus forms, Jonathan with 14, Oldenburg with 9, Tolman with 10, Winesap with 21, Yellow Transparent with 11, and others with smaller numbers. Results have been various; some, in fact a considerable portion of the attempts, failed entirely, while others were in varying degrees successful. All should be repeated before judgment is expressed as to possible performance, and the greater the number of repetitions the better the basis for an opinion regarding what may be expected of a particular mating. As examples of this, these facts may be cited: Grimes X Yellow Siberian Crab (857) in 1912 failed utterly, but the same mating in 1914 was

38 percent successful; Grimes X *Malus floribunda* (821) was 26 percent successful in 1914 and failed entirely in 1915; Grimes X *Malus malus* var. (19667), a crab form of uncertain taxonomic position, gave 34 percent successful pollinations in 1914 but gave no fruits in 1916.

TABLE 8.—VARIETIES USED AS PISTILLATE PARENTS IN GROUP 2, ORCHARD VARIETIES X CRAB-LIKE FORMS OF MALUS

Variety	Number of matings	Number of distinct parental combinations	Flowers pollinated	Fruits matured
1 Akin	11	8	119	4
2 Arkansas	2	2	100	1
3 Ben Davis	8	7	626	72
4 Black Ben Davis	1	1	48	1
5 Collins	4	3	195	2
6 Delicious	6	4	51	0
7 Domine	5	5	119	3
8 Early Ripe	1	1	50	0
9 Fameuse	6	5	135	8
10 Fanny	6	5	50	0
11 Golden Sweet	1	1	51	7
12 Grimes	22	16	712	87
13 Huntsman	3	3	145	19
14 Jefferis	2	2	86	0
15 Jonathan	18	14	646	151
16 Lady	1	1	4	0
17 Longfield	4	4	189	68
18 McIntosh	1	1	46	6
19 Melonen	1	1	46	12
20 Oldenburg	13	9	215	62
21 Oliver	5	4	59	3
22 Osimoe	4	4	189	16
23 Red Astrachan	1	1	3	1
24 Roe's Duchess	2	2	99	49
25 Rome	10	7	686	303
26 Shackleford	3	3	150	47
27 Stayman Winesap	10	8	99	4
28 Summer P. Royal	6	5	248	23
29 Tolman	13	10	493	102
30 Twenty Ounce	3	2	57	1
31 Willow	3	3	146	6
32 Winesap	28	21	778	28
33 Winter Rambo	1	1	48	0
34 Wythe	1	1	48	5
35 Yellow Transparent	13	11	216	10
Total	219	176	6 952	1 101

These cases occur so frequently that they show clearly the futility of attempting to judge the desirability of particular matings from results of one season.

Varieties Used as Pistillate Parents in Matings of Group 2

The varieties utilized as pistillate parents in this group, orchard varieties X crab-like forms of Malus, are tabulated in alphabetical

order in Table 8. They number thirty-five. Each is given the number of matings, the number of distinct parental combinations, number of flowers pollinated, and of fruits matured.

In a considerable number of cases the same combination was attempted in more than one year, so that the actual number of matings was 219 but the distinct combinations of parents only 176. For the varieties Akin, Delicious, Fanny, Lady, Red Astrachan, Oliver, and Stayman Winesap, all flowers pollinated were those of small potted trees forced in the greenhouse. For the varieties Domine, Fameuse, Grimes, Jonathan, Oldenburg, and Winesap, part of the pollinations were in the greenhouse and part in the orchard. For all other varieties the pollinations were wholly on trees in orchard. It may be noted that six varieties—namely, Delicious with four matings and 51 flowers pollinated, Early Ripe with one mating and 50 flowers, Fanny with 5 matings and 50 flowers, Jefferis with two matings and 86 flowers, Lady with one mating and four flowers, and Winter Rambo with one mating and 48 flowers—failed entirely.

Four varieties—Arkansas, Black Ben Davis, Red Astrachan, and Twenty Ounce, with six matings and an aggregate of 208 flowers pollinated—yielded only one fruit each; a number of other varieties gave very low percentages of success. However, if the 6,952 flowers pollinated within the group should be considered in relation to the 1,101 fruits matured, it appears that the ratio 1 fruit for each 6.31 flowers pollinated is higher than the ratio 1 to 7.70 obtained from the aggregates of fruits and flowers of the group orchard varieties X orchard varieties. In this latter group a distinctly higher ratio would naturally be expected because of greater similarity between the plants mated, than would be expected where the plants paired exhibit such extremes in important characters as is the case in the group orchard varieties X crab-like forms.

Forms of Malus Used as Pollen Parents in Matings of Group 2

The species and varieties supplying pollen for the matings in this group number thirty-two. Table 9 shows them arranged in order of the number of matings in which used, together with the number of varieties on which each was used, the number of flowers pollinated, and the number of fruits produced.

These 32 forms of Malus supplied pollen for the 176 distinct combinations of parents; 12 of them used twenty-six times on 25 varieties and involving the pollination of 184 flowers failed to effect fertilization, or at least developed no fruits. The number of matings was 219 and of these 115, involving 1,990, or 28.62 percent of the flowers pollinated, failed. Of the 176 distinct parental combinations 81, including 1,493 flowers pollinated, or 21.48 percent of the total pollinations, failed; fruit production was then distributed among 94

distinct parental combinations and followed pollination of 5,459, or 78.52 percent of all flowers used. All the fruits produced, 1,101 in number, came from 104 matings and followed pollination of 4,962, or 71.38 percent of all flowers used.

TABLE 9.—POLLEN PARENTS IN GROUP 2, ORCHARD VARIETIES X CRAB-LIKE FORMS OF MALUS

Species or variety	Times used	Number of varieties on which used	Flowers pollinated	Fruits matured
1 *M. ringo*.....(840 & 19662).....	25	11	310	13
2 *M. niedwietzkyana*.....(834).....	19	14	308	32
3 *M. floribunda*.....(821).....	18	12	985	205
4 *M. prunifolia* var.....(838).....	17	14	991	246
5 *M. siberica frutico coccinea* (19643).....	12	12	331	25
6 *M. microcarpa*.....(19644).....	13	10	134	5
7 *M. baccata*, red fruit.....(806).....	12	11	537	72
8 *M.* Yellow Siberian Crab....(857).....	12	9	708	132
9 *M. malus* var.....(19667).....	9	6	135	20
10 *M. baccata maxima*.....(810).....	9	8	504	55
11 *M. atrosanguinea*.....(804).....	7	5	275	75
12 *M. sylvestris fastigiata bifera*.(820).....	6	5	127	16
13 *M.* Whitney Crab.....	6	6	290	24
14 *M. prunifolia* var.....(856).....	5	5	243	67
15 *M. arnoldiana*.....(802).....	4	4	150	4
16 *M. baccata*, red fruit, late....(807).....	4	4	197	41
17 *M. coronaria*.....(818).....	4	4	22	0
18 *M. baccata sieboldi*.....	4	4	197	25
19 *M.* Fluke Apple.....(822).....	4	4	16	0
20 *M. scheideckeri*.....(19646).....	4	4	21	2
21 *M. toringo*.....(852 & 19664).....	4	4	182	10
22 *M. soulardi*.....(846).....	3	3	21	0
23 *M. toringo*.....(851).....	3	2	11	0
24 *M. malus fl. pl.*.....(833).....	3	3	143	32
25 *M. prunifolia xanthocarpa*...(839).....	2	2	10	0
26 *M. baccata oblonga*.....(811).....	2	2	17	0
27 *M. sargenti*.....(843).....	2	2	18	0
28 *M. malus pendula*.....(832).....	2	2	14	0
29 *M. halliana*.....(823).....	1	1	5	0
30 *M. ioensis fl. pl.*.....(826).....	1	1	4	0
31 *M. spectabilis*.....(848).....	1	1	10	0
32 *M. toringo*.....(843).....	1	1	36	0
Total.....	219	176	6 952	1 101

Of the 6,952 flowers pollinated 5,912, or approximately 85 percent, were on trees in orchard and 1,040, or about 15 percent, were on potted trees in the greenhouse. Of the fruits harvested, 1,050, or a little over 95 percent, were from pollinations in the orchard, while 51 or nearly 5 percent were from the house. Examining the ratios, however, it appears that the ratio of success inside was distinctly higher than that for outside pollinations; in other words it required pollination of 2.04 flowers to produce one fruit in the house, while 5.63 flowers were used to produce one fruit from pollinations in orchard. The

division of the 219 matings as between house and orchard was 104, or approximately 48 percent, in the house, and 114, or above 52 percent, in the orchard. The average of flowers to each mating is exactly 10 for the house and more than five times that number, or nearly 52 for matings in orchard. The ratio of fruits to flowers pollinated is higher for the house than for the orchard as is also the percentage of matings that failed entirely.

This failure of a much greater number of the inside matings may be ascribed, in part, to the often very small numbers of flowers pollinated, and in part to age differences between the trees employed; the orchard trees were all mature and well-established in fruit production, while those used in the greenhouse were all young, most of them flowering for the first time and producing but few clusters of flowers that were not infrequently defective. It is a common experience that young apple trees, whether growing in orchard or under glass, fail in the first efforts at fruit production. They produce a few flowers, but the reproductive function is still subordinate to the vegetative function, flowers are imperfect in structure or are incapable of performing proper functions; hence, pollination of such flowers fails. While this condition is almost universal with young trees of orchard varieties, it is less common with the crab-like species. In the group under consideration the pistillate parents are all orchard varieties; the plants of these varieties available for use in the house were in great part young trees making their initial effort in flower production and the large number of failures is due doubtless to the infertile condition of these first flowers.

Performance of Certain Orchard Varieties When Pollinated by Crab-like Forms

The details of the performance of a few of the orchard varieties when pollinated with pollen of crab-like forms may be given briefly at this time, beginning with Akin.

Akin is represented by two trees from scions grafted March 1, 1910, one on paradise, the other on Doucin stock, the stocks being then in 8-inch pots. No difference in growth of the trees that could be attributed to differences in stocks had been observed; both flowered in March, 1914, and the flowers were pollinated. Neither flowered in 1915 but both flowered in 1916, and one of the pair—the one on Doucin—flowered again in 1917. On March 14, 1914, 5 flowers on the tree on Doucin stock were pollinated with pollen from *M. niedwietzkyana* (834); no fruits developed. On April 1 of the same year, flowers on the tree on paradise stock were pollinated as follows: 4 flowers with pollen of *M. ringo* (19662); 5 flowers with pollen of *M. coronaria* (818); and 5 flowers with pollen of *M. halliana* (823).

These pollinations also failed. Two years later, in March, 1916, 34 flowers on the tree on paradise were pollinated with pollen of *M. ringo;* 4 fruits developed which yielded 33 seeds, 29 of which germinated. On the same tree, 11 flowers were pollinated with pollen from *M. soulardi* (846) but no fruits resulted. Flowers borne by the tree on Doucin stock were pollinated as follows: 6 with pollen of *M. microcarpa* (19644); 6 with pollen of *M. malus* var. (19667); 18 with pollen of *M. siberica frutico coccinea* (19643); 17 with pollen from *M. ringo* (840); and 8 with pollen from *M. niedwietzkyana* (834), a total of 55 flowers with five distinct pollen parents; no development of fruit followed. Thus for this variety there were 119 pollinations by eight distinct pollen producers; seven of the eight failed entirely, and one, *M. ringo,* gave 4 fruits from 34 flowers pollinated, or 11.75 percent. The reciprocal of this partially successful cross gave 13 fruits from 27 pollinations, or approximately 48 percent success. Reciprocals of the crosses with *M. soulardi* and *M. coronaria* both failed, but Akin pollen used on one form of *M. prunifolia* was 14 percent successful, and on *M. baccata oblonga* 6 of 7 flowers pollinated developed fruits, a success percentage of 85.71. The small success attained in the role of mother plants is not due to any inherent defect in the variety, but to immaturity of the individuals used. Orchard trees of this variety now in the tenth year from the graft have not flowered and it is believed that late development of the reproductive function is characteristic.

Grimes was mated twenty-two times with 16 different forms of Malus as pollenizers. The flowers pollinated aggregate 712 and the fruits matured number 87, giving a success percentage of 12.21. Both orchard and greenhouse pollinations are represented: thirteen matings were on trees in orchard and nine on young trees in greenhouse. All of the latter failed, as did also four of the orchard matings. Thus the 87 fruits are the product of nine orchard matings. The percentages of success in these matings range from 2.08 for the cross Grimes X *M. prunifolia* (838), with 48 flowers pollinated and only 1 fruit harvested, to 42 percent for the cross Grimes X *M. baccata* (807), with 50 flowers pollinated and 21 fruits matured. The four orchard matings that failed were: a 1912 mating with Yellow Siberian Crab (857), with 47 flowers pollinated (this same mating in 1914, with 50 flowers pollinated, was 38 percent successful); a 1913 mating with *M. atrosanguinea* (804) using 45 flowers (repeated in 1915 this mating gave 5 fruits from 43 pollinations); a 1913 mating with *M. floribunda* (821) using 33 flowers (this repeated in 1914 gave 13 fruits from 50 flowers, or a success percentage of 26); and a single mating in 1916 with *M. prunifolia* var. (856), with 49 flowers pollinated.

None of these failures were attended with any circumstances indicating or suggesting causes of infertility. The partial success

attained in repetition of three of the four crosses eliminates any suggestion of habitual infertility between the plants mated and in these cases cause of failure must be held to rest in some undetermined seasonal or local condition. The cross with *M. prunifolia* var. (838) was not repeated, but any suspicion of defective pollen is eliminated by the fact that pollen from the same dish used on Longfield stigmas gave 30 fruits from 46 flowers pollinated, or a success percentage of more than 65. Failure of pollinations in the greenhouse is ascribed in part, as in the case of Akin, to the use of first flowers borne by young trees. In part, failure may have been due to violence of the cross, for in the two matings with *M. niedwietzkyana* the extremes of Malus forms meet. This Turkestan species, because of its very distinctive characters, has been used as a pollenizer in 19 matings on 14 varieties; 12 of these matings on 7 varieties have failed, and 7 matings on 7 varieties have given percentages ranging from 3.4 for the mating with Jonathan to 50 percent for the matings with Yellow Transparent. Failure of Grimes to accept pollen of this species, even for two matings in different years, does not definitely establish the relation between the two because of these two facts—the small numbers of flowers pollinated and the immaturity of the Grimes trees. Further matings, with increased numbers of pollinations on more mature trees, may give quite different results.

Jonathan was mated eighteen times with 14 species and varieties of Malus. The aggregate of flowers pollinated was 646 and the fruits harvested numbered 151; this gives 23.37 as the percentage of success with a ratio of 1 fruit for each 4.27 flowers. Eight of the matings were in the greenhouse and ten in the orchard. All the inside pollinations were on a single Jonathan tree, pot-grown from graft inserted March 5, 1913, on paradise stock, and flowering for the first time in March, 1916. The tree bore 117 flowers, all of which were pollinated. The net result was 1 fruit from one of 29 flowers pollinated by *M. niedwietzkyana;* this contained 7 seeds, 5 of which germinated. There was complete failure in three of the ten matings in the orchard. These failures occurred in the spring of 1913, and the pollen plants were *M. floribunda* (821) with 47 pollinations, *M. prunifolia* var. (838) with 47, and *M. baccata maxima* (810) with 46; no other matings between Jonathan and members of the crab group were attempted in that year and no satisfatory reasons for the failures were found. Pollen of *M. floribunda* (821) failed on Grimes in the season of 1913, but was partially successful on Fameuse; pollen of *M. baccata maxima* (810) was highly successful in that year on Rome and successful in lesser degree on Osimoe, while pollen of *M. prunifolia* var. (838) used on 28 flowers of Ben Davis failed there, as on the 47 flowers of Jonathan. In 1914 the matings with *M. floribunda* (821)

and *M. baccata maxima* (810) were repeated; the former was 30 percent, and the latter 22 percent successful. The 1913 mating with *M. prunifolia* (838) repeated in 1915 gave 38 fruits from pollination of 49 flowers, or a success percentage of 77.55. This was the highest success attained in any cross between Jonathan and one of the crab group.

The seven orchard crosses that produced fruits in percentages ranging from nearly 16 for the cross Jonathan X *M. sylvestris fastigiata bifera* (820) to 77.5 for the cross Jonathan X *M. prunifolia* var. (838) included 389 pollinations and produced 150 fruits, or 1 fruit for each 2.59 flowers pollinated.

Oldenburg has been paired with nine members of the crab group in thirteen matings. Flowers pollinated numbered 215 and fruits matured, 62. Ten of the matings with 6 different species, and including 69 pollinations which matured 9 fruits, were made in the greenhouse; and three including 146 pollinations yielding 53 fruits were made in orchard. The success percentage for all pollinations was 28.83, and the ratio of fruits to flowers pollinated was 1 to 3.46. For the greenhouse matings the success percentage was 36.30, and the ratio 1 to 2.73. Five of the greenhouse matings, with 38 pollinations, failed; the 9 fruits from greenhouse pollinations resulted from five matings including 31 pollinations by three species, as follows: pollen of *M. malus* var. (19667) on five flowers in 1914 gave one fruit and on 11 flowers in 1916 gave two fruits; pollen of *M. ringo* (840) on three flowers in 1915 gave two fruits and on nine flowers in 1916 gave one fruit; and pollen of *M. microcarpa* (19644) on three flowers in 1916 gave three fruits. The failures were, *M. siberica frutico coccinea* (19643) on six flowers in 1913; *M. prunifolia xanthocarpa* (839) on five flowers in 1914; *M. niedwietzkyana* on four flowers in 1914 and on 19 flowers in 1916; and *M. ringo* (19662) on four flowers in 1916. All of the failures were on trees flowering for the first time altho these trees are on paradise stocks four and five yeears old from the graft. While the first flowers borne usually fail this is not always the case, as is illustrated in one mating by *M. malus* var. (19667) in which, on a tree one year old from graft on paradise stock, pollination of five of the six flowers in the single cluster yielded one mature fruit. The test of Oldenburg in orchard mated with species of Malus covers only three species and is not as extensive as is desirable, but so far as it goes results are satisfactory; the percentages of success are distinctly above the average for this group of orchard varieties X crab-like forms.

Rome has had 686 pollinations distributed in ten matings with eight different forms of Malus. Two of these forms are under the same name, Yellow Siberian Crab, but as they are quite distinct the identity of each has been maintained in the records. The matings

TABLE 10.—DISTRIBUTION OF SEEDS IN HYBRID FRUITS OF GROUP 2, ORCHARD VARIETIES X CRAB-LIKE FORMS OF MALUS

Variety	Number of parental combinations	Number of fruits	Number of seeds	Average number of seeds to 1 fruit	Seeds to each fruit																
					0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Akin	1	4	33	8.25	...	...	...	...	...	...	1	1	...	1	...	1	...	...	...	...	...	...
2 Arkansas	1	1	8	8.00	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
3 Ben Davis	7	72	304	4.22	2	5	7	9	19	13	8	5	3	...	1	...	...	...	...	...	...	...
4 Black Ben Davis	1	1	0	....	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5 Collins	1	2	16	8.00	...	...	...	...	...	...	...	1	...	1	...	...	...	...	...	...	...	...
6 Domine	1	3	37	12.33	...	...	...	...	...	...	...	...	...	...	...	1	2	...	...	...	...	...
7 Fameuse	3	8	54	6.75	...	...	...	...	...	1	2	3	2	...	...	...	...	...	...	...	...	...
8 Golden Sweet	1	7	26	3.71	...	...	3	1	1	1	...	...	1	...	...	...	...	...	...	...	...	...
9 Grimes	9	87	735	8.44	...	...	2	2	...	...	6	7	15	30	25	...	...	...	...	...	...	...
10 Huntsman	3	19	257	13.52	...	...	...	...	...	...	...	...	2	1	1	2	1	...	2	3	4	3
11 Jonathan	8	151	885	5.86	5	3	3	6	11	32	28	31	21	9	2	...	...	...	...	...	...	...
12 Longfield	4	68	498	7.32	...	1	1	...	3	2	14	10	18	15	4	...	...	...	...	...	...	...
13 McIntosh	1	6	35	5.83	...	...	...	...	2	...	1	3	...	...	...	...	...	...	...	...	...	...
14 Melonen	1	12	132	11.00	...	...	...	...	...	1	1	...	...	2	1	1	1	2	4	...	...	...
15 Oldenburg	6	62	348	5.61	...	2	4	6	7	14	6	10	5	4	4	...	...	...	...	...	...	...
16 Oliver	1	3	20	6.66	...	...	...	...	1	...	...	1	...	1	...	...	...	...	...	...	...	...
17 Osimoe	4	16	137	8.56	...	...	...	...	...	...	1	2	3	7	3	...	...	...	...	...	...	...
18 Red Astrachan	1	1	4	4.00	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...	...
19 Roe's Duchess S	2	49	425	8.67	...	...	...	...	1	...	4	7	8	14	10	3	1	1	...	...	...	...
20 Rome	7	303	2 181	7.19	10	4	6	5	8	23	39	57	61	44	29	9	7	1	...	...	...	...
21 Shackleford	3	47	335	7.12	1	...	2	4	1	6	1	9	9	5	2	5	2	...	...	...	...	...
22 Stayman Winesap	2	4	1	0.25	3	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
23 Summer P. Royal	2	23	183	7.95	...	...	...	1	...	2	1	3	5	7	4	...	...	...	...	...	...	...
24 Tolman	9	102	812	7.96	...	...	2	3	3	5	4	15	21	26	22	1	...	...	...	...	...	...
25 Twenty Ounce	1	1	8	8.00	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...
26 Willow	2	6	48	8.00	...	...	...	...	...	...	...	3	1	1	1	...	...	...	...	...	...	...
27 Winesap	8	28	251	8.96	...	...	...	...	...	...	...	1	10	7	9	1	...	...	...	...	...	...
28 Wythe	1	5	21	4.20	...	...	2	...	1	1	...	...	1	...	...	...	...	...	...	...	...	...
29 Yellow Transparent	4	10	68	6.80	...	...	1	...	...	1	2	3	1	...	2	...	...	...	...	...	...	...
Total	95	1 101	7 862	.....	22	16	33	37	59	102	119	172	189	175	120	24	11	6	6	3	4	3

with *M. prunifolia* var. (838) and *M. floribunda* (821) made in 1914 were repeated in 1915 and the two matings for each are here combined. The fruits matured aggregate 303, represent 44.16 percent of the pollinations, and give a ratio of one fruit for each 2.26 flowers pollinated. This is considerably above the success percentage of 34.83 and the ratio of fruits to flowers pollinated of 1 to 2.87 recorded for Rome in group 1 where the pollen was supplied by orchard varieties. There were no entire failures. The lowest success percentage is found in the cross Rome X *M. baccata* (806) where 46 pollinations gave four fruits, a percentage of 8.7; the highest success is recorded in 117 fruits from 200 pollinations by *M. prunifolia* var. (838) giving 58.5 as the success percentage. All the Rome pollinations here considered were made on one individual, a tree about twenty years old. It is not known whether or not other individuals of the variety possess the same fertility, but surely this one is a good breeder and its performance very gratifying.

Seed Production in Hybrid Fruits of Group 2

The total seeds saved from the 1,101 fruits produced by the matings within this group of orchard varieties X crab-like forms was 7,862 (Table 10). The average number of seeds to each fruit is then 7.14, which is slightly higher than the average of 7.06 for the 990 fruits of the group orchard varieties X orchard varieties. Seed production of individual fruits ranged from 0 to 17. There were 22 parthenocarpic fruits, 16 that produced 1 seed each, 33 that produced 2 seeds each, and 37 that produced 3 each; at the other extreme 3 fruits produced the maximum of 17, 4 fruits had 16 each, 3 had 15 each, and 6 had 14 each. The highest frequency fell upon 8 seeds each and this was represented by 189 fruits, or 17.17 percent of the total number; 352 fruits, or 31.97 percent, ranged above this highest frequency, and 560 fruits, or 50.86 percent, produced seeds in less numbers than eight or were seedless.

Of the 35 varieties used as mothers in this group, 6—namely, Delicious, Early Ripe, Fanny, Jefferis, Lady, and Winter Rambo—produced no fruits and hence have no representation in the seed distribution list. The 29 varieties yielding fruits range widely both in numbers of fruits and in seed distribution. Huntsman with 19 fruits leads all others in high seed production, with an average of 13.52 seeds to each fruit and a distribution range from 8 as the minimum for 2 fruits to 17 as the maximum for each of 3 fruits. The maximum next below Huntsman is 14 seeds reached by 4 fruits of Melonen. This variety is represented by only 12 fruits; its minimum is 5 seeds for 1 fruit followed by one with 6 seeds, 2 with 9 each, 1 each with 10 and 11, and 2 with 13 each; its average is 11. Three varieties reach a maximum of 13 seeds—Domine with 2 fruits, Roe's Duchess Seed-

ling and Rome with 1 fruit each. Three varieties, each producing 1 fruit, had seeds as follows: Arkansas and Twenty Ounce, 8 each; Red Astrachan, 4. The 22 parthenocarpic fruits were distributed among 6 varieties: Ben Davis had 2, Black Ben Davis had 1, Jonathan had 5, Rome had 10, Shackleford had 1, and Stayman Winesap had 3.

With regard to the normal of 10 seeds to each apple, there are 18 that reached and 9 that exceeded this number; the aggregate of fruits having 10 seeds each is 120, or approximately 11 percent of all fruits. The 11 varieties that fall short of 10 seeds to each fruit represent 924, or 83.92 percent of the total number of fruits. Comparison of the behavior of particular varieties is scarcely possible because of diversity in the parental combinations, seasonal differences, and the fact that many of the varieties were represented by very small numbers of fruits. Table 10 gives the seed distribution for all the 95 fruiting combinations grouped according to varieties serving as pistillate parents.

Season of Maturity of Hybrid Fruits

The period during which hybrid fruits are picked and described is somewhat prolonged, extending for all seasons including 1916 from June 16 to November 10, but varying somewhat in different seasons. Hybrid fruits developed from pollinations of orchard varieties by species of Malus in the greenhouse in March and April have picking dates ranging from June 16 for Yellow Transparent to September 28 for Akin; for fruits from orchard trees the range of picking dates was from July 27 for Yellow Transparent to November 10 for Ben Davis, Collins, and Winesap.

It is desirable that, when picked, the fruits of summer and fall varieties be of edible rather than of commercial maturity in order to judge accurately such characters as color, texture of flesh, and flavor, but in the absence of cold storage facilities it has been impossible to describe all fruits when in the ideal condition. There have been errors in both directions; in some cases fruits have been picked that should have remained on the trees a few days longer, but the most frequent mistake has been in allowing fruits to reach a somewhat over-ripe condition. A succession of hot days near the time of normal maturity so hastens the ripening processes that the number of fruits ready for description on a given day may be in excess of the number that can be cared for; those subjected to delay rapidly deteriorate and description is less satisfactory. With the advent of anticipated cold storage, this difficulty will be largely eliminated, for by arranging for more frequent inspection it appears possible that all fruits may be picked at just the proper time for most accurate record and held at a low temperature until description can be made, thus eliminating

the haste that is now often necessary, and insuring a more satisfactory record.

Losses of Seeds Between Extraction and Planting

Under the system practiced in handling the seeds of hybrid fruits, as explained in connection with Group 1, seeds of fruits from greenhouse pollinations have been held before planting for periods varying between 69 and 173 days, and those from fruits on orchard trees from 26 to 113 days. The aggregate of seeds saved from the 1,101 fruits of this group was 7,862, or an average of 7.14 seeds to each fruit. The number of seeds planted was 7,512; this shows a loss of 350 seeds in the interval of dry storage, or 4.45 percent of the total seeds saved. This percentage of loss is appreciably smaller than that recorded for Group 1, which was nearly 8 percent, and appears to be due to the fact that in Group 2 there were noticeably less numbers of ovules developing what appeared to be good seeds but which were without embryos.

Percentage of Germination Higher in Group 2 Than in Group 1

The percentage of germination recorded for the seeds in Group 1 was 62.22. For Group 2 this percentage is distinctly higher. The number of seeds planted was 7,512; of these 5,408 are recorded as having germinated. This is 71.99 percent of the number of seeds planted and, for apple seeds artificially hybridized, may be regarded as a fairly satisfactory percentage. As was the case in Group 1, there is wide variation between the varieties in the matter of germination. There were three matings in which all seeds failed to germinate; Arkansas X Yellow Siberian Crab (857), in which 50 flowers pollinated in orchard in 1914 yielded 1 fruit from which 4 seeds were planted; Stayman Winesap X *M. niedwietzkyana* (834), in which 6 flowers pollinated in the greenhouse in 1916 yielded 1 fruit from which 1 seed was planted; and Yellow Transparent X *M. scheideckeri* (19646), in which 3 flowers pollinated in the greenhouse in 1915 yielded 2 fruits from which 13 seeds were planted. Thus these three matings involve 59 pollinations and 4 fruits with 18 seeds. Arkansas has proved a very unsatisfactory mother, and efforts thus far made to hybridize it have been unsuccessful; 50 pollinations by *M. prunifolia* var. (856) failed entirely, and 50 pollinations by Yellow Siberian Crab developed one fruit as stated above; this fruit had 8 seeds, 4 of which were planted, but none germinated; in addition 273 pollinations divided among 4 orchard varieties yielded no fruits. The one tree used is in orchard, more than twenty years old, and with a record of abundant bloom and very few fruits. Stayman Winesap has no better record than Arkansas; 99 pollinations have been made by

8 different forms of Malus; 6 of the attempts gave no fruits, one gave 3 seedless fruits, and the remaining one is that referred to above.

These pollinations were all on potted dwarf trees in the greenhouse and it is probable that failure should be ascribed to the youth of the trees and the utilization of the first flowers borne. Yellow Transparent has scored more failures than successes; four of thirteen matings with eleven different forms of Malus gave degrees of success as follows: 44 flowers pollinated in orchard by *M. prunifolia* (838) yielded 2 fruits containing 18 seeds, 8 of which germinated; 3 flowers pollinated in the greenhouse by *M. scheideckeri* (19646) gave 2 fruits with 13 seeds, none of which germinated (this is the mating previously referred to. Pollination of 10 flowers in the greenhouse by *M. niedwietzkyana* gave 5 fruits with 30 seeds, 22 of which, or 73.33 percent, germinated; 11 flowers, also in the greenhouse, pollinated by *M. ringo* (840) gave 1 fruit and 6 seeds, 3 of which germinated. The nine matings that failed entirely were: in orchard, 48 flowers by *M. baccata* (807), 40 flowers by *M. toringo* (19664), and 19 flowers by *M. baccata maxima* (810); in greenhouse, 4 flowers in 1914 by *M. microcarpa* (19644), 5 flowers by *M. coronaria* (818), 4 flowers by *M. ioensis fl.pl.* (826), 10 flowers by *M. siberica frutico coccinea* (19643), 5 flowers in 1916 by *M. microcarpa* (19644) and 13 flowers by *M. ringo* (19662).

Summarizing the attempts to hybridize Yellow Transparent with forms of Malus it appears that 216 pollinations were made, 10 of which, or 4.63 percent, were successful; that is, this number produced fruits. The ratio, 1 fruit for 21.6 flowers, is low. These fruits contained 68 seeds, and of the 67 which were planted 33, or 49.25 percent, germinated. Of the 33 seedlings, 31 are now living, 6 of them in orchard now six years old, and the balance in the nursery. While the record of Yellow Transparent is low as to fruit production the performance of the seeds is fairly creditable. For five of the matings all seeds produced are recorded as having germinated, but in all of these the numbers of seeds are small. Four of the matings had but 1 fruit each and the other 3 fruits; they are as follows: Ben Davis X *M. baccata maxima* (810) 4 seeds from 1 fruit, Domine X *M. baccata* var. (806) 37 seeds from 3 fruits, Tolman X *M. atrosanguinea* (804) 6 seeds from 1 fruit, Tolman X *M. sylvestris fastigiata* (820) 5 seeds from 1 fruit, and Twenty Ounce X *M. ringo* (19662) 8 seeds from 1 fruit; this last was from greenhouse pollinations, the others were from pollinations in orchard.

Naturally the varieties represented by the largest numbers of seeds give the most satisfactory records because the strength of numbers adds to the reliability of percentages and supplies a better basis from which to estimate performance; thus for Akin 29 seeds, or 87.87 percent of the 33 planted, germinated, and for Collins 3 seeds, or

18.75 percent of the 16 planted, germinated, which are the extremes of germination. Percentages in this group are not such satisfactory indices of the possibilities of the varieties as are the percentages for Rome, Grimes, Jonathan, or Tolman. These 4 varieties have records as follows: Rome from ten matings with 7 different crab-forms gave 303 fruits; from these fruits 2,115 seeds were planted and 1,721, or 81.34 percent, germinated; Grimes gave only 12.25 percent of success in fruit production, but from the 87 fruits from matings with 16 forms of Malus, 722 seeds were planted, 608, or 84.21 percent, of which germinated. Jonathan from 646 flowers pollinated by 14 different crab-forms gave 151 fruits; from these 835 seeds were planted and 598 germinated; this is 71.61 percent of successful germination. Tolman was mated with ten different forms and nine of them produced 102 fruits; of the 796 seeds planted 563, or 70.90 percent, germinated.

Hybrid Seedlings Now Living

When the living hybrid seedlings were enumerated late in the fall of 1916, those originating from pollinations in Group 2 numbered 4,001, ranging in age from one to five years. The number of seeds recorded as having germinated was 4,848, so that the number of seedlings lost up to the time of the last enumeration was 847, or 17.47 percent. This represents the loss percentage of the aggregate of seedlings. If division is made into annual groups, the loss percentages vary widely, and naturally the older groups exhibit the highest percentages of loss because they have had a longer time in which to eliminate weak seedlings, and also because the seedlings have been subjected for a longer period to the ravages of insects and diseases and all the accidents that commonly befall young seedlings. Since the enumeration of seedlings in the fall, the seeds from fruits derived from pollinations in 1916 have been planted, the record of germination has been obtained, the living seedlings have been planted in nursery, and the record of the group, so far as it goes, may be included with the older groups of seedlings. The aggregate of seeds germinated for all seasons, 1911 to 1916, is 5,408 and the number of seedlings now living is 4,533, which represents 83.82 percent of the germinations. The relation of the year groups to each other is shown in Table 11. The four older groups of trees are now in the orchard, the lot from pollinations in 1914 having been planted in April of the present year; the two younger lots are in the nursery.

Comparing Table 11 with the similar one for Group 1 (Table 3), the differences appearing are not such as to suggest any striking differences in persistence of the seedlings of the two groups. Group 2 had nearly 35 percent more seeds and more than 53 percent more trees than had Group 1; the distribution over the different years is less uniform, and as for percentages of seedlings living, the one-, three-, and five-

year-old trees have higher percentages in Group 1 than in Group 2, while for the two- and four-year-old trees the higher percentages are those of Group 2. Percentages of the aggregate are 73.67 for Group 1 and 83.82 percent for Group 2.

Individual Records in Group 2

As illustrations of the behavior of orchard varieties when pollinated by crab-like forms of Malus, detailed record of certain of the

TABLE 11.—NUMERICAL RELATION OF LIVING SEEDLINGS TO SEEDS GERMINATED IN GROUP 2, ORCHARD VARIETIES X CRAB-LIKE FORMS OF MALUS, WITH PERCENTAGES AND AGES OF TREES

Year	Seeds germinated	Trees living		Age of trees, *yrs.*
		Number	Percentage	
1911	54	35	64.81	5
1912	351	227	64.67	4
1913	161	115	71.42	3
1914	2 208	1 776	80.43	2
1915	2 074	1 848	89.10	1
1916	560	532	95.00	¼
Total	5 408	4 533	83.82	

varieties may be given in the same manner as for certain individuals of Group 1, and as in that group, Oldenburg may be considered first. Flowers of Oldenburg were pollinated by 9 different members of the crab group in thirteen matings, five of which failed to produce fruits. The aggregate of flowers pollinated was 215, of which number 62, or 28.83 percent, yielded mature fruits. Only three of the thirteen matings were on trees in orchard. These included 146, or 67.9 percent, of flowers pollinated and produced 53, or 85.48 percent, of the total number of fruits. Of the ten matings with 6 Malus forms, five, with 38 pollinations, failed to produce fruits, and five, with 31 pollinations, produced 9 fruits (Table 12). Because of difference in numbers of pollinations and the fact that the tabulation for Oldenburg in Group 1 involved only orchard pollinations, while the tabulation in Group 2 includes a large proportion of inside matings, the two tabulations are not readily compared, but it may be pointed out that for Group 1 the ratio of fruits to flowers pollinated is 1 to 2.44, and in Group 2 this ratio is 1 to 3.46, or, to state the relation in percentages, pollinations were 40.85 percent successful in Group 1, and 28.83 percent successful in Group 2. In the matter of germination the advantage lies the other way. Of the seeds planted from pollinations in Group 1, 56.75 percent germinated, and in Group 2 this percentage was 61.38. The percentage of seedlings persisting in Group 1 was 82.7; in Group 2, 89.2. This difference is small and when the age differences are considered it may

TABLE 12.—OLDENBURG POLLINATED BY NINE MEMBERS OF THE CRAB GROUP

Oldenburg X	Year	Flowers pollinated	Fruits picked	Percentage of success	Number of seeds			Percentage germinated	Seedlings living June, 1917
					Saved	Planted	Germinated		
1 *M. siberica*.....(19643).....	Gh. 1913	6	0	0.00	...	...	...	....	....
2 *M. prunifolia xanthocarpa*.....(839).....	Gh. 1914	5	0	0.00	....	....	....	....	....
4 *M. malus* var.....(19667).....	Gh. 1914	5	1	20.00	2	2	1	50.00	1
5 *M. malus* var.....(19667).....	Gh. 1916	11	2	18.18	14	13	7	53.84	7
6 *M. niedwietzkyana*.....(834).....	Gh. 1914	4	0	0.00	....	....	....	....	....
7 *M. niedwietzkyana*.....(834).....	Gh. 1916	19	0	0.00	....	....	....	....	....
8 *M. ringo*.....(840 & 19662).....	Gh. 1915	3	2	66.67	12	12	2	16.67	2
9 *M. ringo*.....(840 & 19662).....	Gh. 1916	9	1	11.11	5	5	2	40.00	2
10 *M. ringo*.....(840 & 19662).....	Gh. 1916	4	0	0.00	....	....	....	....	....
11 *M. microcarpa*.....(19644).....	Gh. 1916	3	3	100.00	15	15	14	93.33	14
12 *M. prunifolia* var.....(838).....	Gh. 1915	50	11	22.00	76	76	49	64.47	37
13 *M. baccata* var.....(806).....	1915	47	16	34.04	123	123	86	69.92	82
14 *M. malus fl. pl.*.....(833).....	1916	49	26	53.24	101	101	52	51.48	45

TABLE 13.—ROME POLLINATED BY TEN CRAB-LIKE SPECIES AND VARIETIES

Rome X	Year	Flowers pollinated	Fruits picked	Percentage of success	Number of seeds			Percent-germinated	Seedlings living	
					Saved	Planted	Germinated		Number	Age, *yrs.*
1 *M. malus* var.....(856)....	1912	48	8	16.67	57	39	26	66.67	18	4
2 Yellow Siberian Crab....(857)....	1912	49	9	18.37	67	49	42	85.71	35	4
3 Yellow Siberian Crab....(857)....	1914	98	52	53.06	404	396	286	72.22	250	2
4 *M. baccata max*.....(810)....	1913	48	18	37.50	112	103	95	92.23	64	3
5 *M. prunifolia* var.....(838)....	1914	100	56	56.00	339	327	269	82.26	205	2
6 *M. prunifolia* var.....(838)....	1915	100	61	61.00	451	451	386	85.59	352	1
7 *M. floribunda*.....(821)....	1914	50	23	46.00	154	154	129	84.42	123	2
8 *M. floribunda*.....(821)....	1915	97	53	54.63	413	412	326	76.51	287	1
9 *M. atrosanguinea*.....(804)....	1915	50	19	38.00	151	151	136	90.07	110	1
10 *M. baccata* var.....(806)....	1915	46	4	8.70	34	34	26	76.47	25	1

be ignored. The rate of seed production is somewhat better for pollinations by orchard varieties than for those by crab-like forms of Malus. For Group 1 there were saved 6.62 seeds for each fruit, while for Group 2 there were only 5.61 seeds for each fruit. Between extraction and planting 95 seeds were lost, or about 65 percent in Group 1, while in Group 2 only 1 of the 348 seeds was lost, or little more than ¼ of 1 percent.

As a second illustration of the behavior of orchard varieties pollinated by crab-like forms, Rome, which has been considered in its relation to orchard varieties as pollenizers, may be used. This variety, as it appears in Group 2, was pollinated by 8 different forms of Malus in ten distinct matings. Two of the forms appear under the same name Yellow Siberian Crab, but one has in addition the number 857. The one without the number was a large spreading tree twenty or more years old; the one carrying the number 857 was a small tree six years of age at the time its pollen was used, extremely upright in habit, and with fruit larger but of the same yellow color as that produced by the large tree. The two forms came from widely different sources and are held to be varietally distinct.

Percentages of success range from 8.7 for the cross Rome X *M. baccata* (806), in which 46 flowers pollinated gave 4 fruits, to 61 for the cross Rome X *M. prunifolia* (838), in which 100 flowers pollinated gave 61 fruits. For all the crosses the success percentage is 44.16. This is distinctly higher than the percentage (34.33) found for the group of Rome crosses with orchard varieties (Table 13).

Pollinations in this group of Rome crosses aggregate 686 and the fruits number 303. This is a ratio of 1 fruit for each 2.26 flowers pollinated, which indicates a somewhat better performance than is recorded for the group of crosses, Rome X orchard varieties, in which the ratio of fruits to flowers pollinated is 1 to 2.87. The two groups are alike in that all crosses in both are on trees in orchard and that no entire failure appears in either. In the two groups, percentages of success range somewhat widely but are reasonably satisfactory in both. The ratio of seeds saved to fruits is 6.72 seeds to each fruit in Group 1, and 7.2 seeds to each fruit in Group 2. Loss of seeds between extraction and planting is much higher for Group 1 than for Group 2, amounting to 10 percent for the former and approximately 3 percent for the latter. For the pollinations by orchard varieties, seed germination reaches 70.54 percent and for pollinations by crab-like forms of Malus, 81.33 percent. So, too, in persistence of seedlings the higher percentage is found in Group 2, and the difference is considerable (68.81 percent for Group 1 and 85.35 percent for Group 2), but some allowance must be made here for the fact that a larger proportion of the seedlings of Group 2 fall into the very young groups.

No variety used has a higher breeding record than has Rome; it accepts the pollen of orchard varieties and, with equal facility, so far as tested, the pollen of quite diverse forms of the crab-group. The proportion of fruits produced is considerably above the average, the seeds are reasonably viable, of average abundance, and the seedlings possess good vitality. As shown in the tabulations, the 12 combinations with orchard varieties and the 8 combinations with crab-like forms are represented by more than 2,000 living seedlings, a large majority of which are expected to reach fruiting maturity. It is regarded as an interesting group because a single individual is the mother of all and the pollen plants contribute extremely diverse characters of flower, foliage, and fruit.

GROUP 3: CRAB-LIKE FORMS OF MALUS X ORCHARD VARIETIES

Forms of Malus Used as Pistillate Parents

Hybrids of this group are the reciprocals of hybrids of Group 2. In Group 3 the pistillate parent was in all cases one of the crab-like forms of Malus, and the pollen the product of a recognized orchard variety. The aggregate of matings within the group was 320 and the number of distinct parental combinations, 245. There were used as mothers 44 different forms of Malus, and the pollen employed came from 29 different orchard varieties. Matings were distributed over the years 1909 and 1911 to 1916, the larger numbers in the later years. In 1909 there were only 3 matings in this group, in 1911 only 4. Plants propagated in 1907 and 1908 commenced flowering in 1912, and for that year there were 33 matings. In 1913 there were 26, and in 1914 the number rose to 88, then dropped to 35 in 1915 because in that year most trees failed to flower. For 1916, the last year for which record is given, the number of matings reached 132. The diversity of the Malus forms used as pistillate parents in this group is perhaps most readily shown by bringing the names together as in Table 14. With each named form is included the number of matings in which it has been used, the number of varieties of pollen used to pollinate its flowers, the number of flowers pollinated, and the number of fruits resulting from the pollinations made.

The forms included in Table 14 exhibit wide diversity in their characteristics but each has its distinguishing marks; the six forms of *M. baccata* all clearly belong to that species, but each has at least one character that readily distinguishes it from any of the others. In the same way the five forms of *M. prunifolia,* while evidently properly associated in specific rank, are distinguished from each other without difficulty. The various forms have been utilized quite unequally, chiefly because some have been more often and more abun-

TABLE 14.—FORMS OF MALUS USED AS PISTILLATE PARENTS IN GROUP 3, CRAB-LIKE FORMS OF MALUS X ORCHARD VARIETIES

Species or variety	Number of matings	Number of parental combinations	Flowers pollinated	Fruits matured
1 *M. arnoldiana*.....(802).....	7	5	1 895	108
2 *M. atrosanguinea*.....(804).....	8	7	604	57
3 *M. baccata*, red fruit.....(806)	5	4	993	201
4 *M. baccata*, red fruit, late....(807).....	6	5	700	253
5 *M. baccata* var .....(808).....	1	1	135	0
6 *M. baccata maxima*.....(810).....	8	5	959	316
7 *M. baccata oblonga*.....(811).....	5	5	77	70
8 *M. baccata* var. *sieboldi*.....(814).....	2	2	376	100
9 *M. coronaria*.....(818).....	5	5	54	5
10 *M. dioica*.....(819).....	7	5	220	14
11 *M. sylvestris fastigiata bifera*..(820).....	15	11	362	121
12 *M. floribunda*.....(821).....	14	11	2 220	138
13 *M. sp(?)* Fluke Apple.....(822).....	5	4	43	5
14 *M. halliana*.....(823).....	2	2	114	0
15 *M. sp(?)* Hyslop Crab .....(824).....	3	3	153	57
16 *M. ioensis*.....(825).....	2	2	185	65
17 *M. ioensis fl. pl*.....(826).....	1	1	10	0
18 *M. malus* var.....(830).....	2	2	94	1
19 *M. malus fl. pl*.....(833).....	1	1	226	10
20 *M. niedwietzkyana*.....(834).....	9	7	290	1
21 *M. prunifolia macrocarpa*....(837).....	6	6	252	8
22 *M. prunifolia* var.....(838).....	15	13	770	421
23 *M. prunifolia xanthocarpa*....(839).....	3	2	91	4
24 *M. ringo*.....(840 & 19662).....	27	11	922	188
25 *M. fusca*.....(841).....	1	1	117	11
26 *M. sargenti*.....(843).....	11	8	235	101
27 *M. soulardi*.....(846).....	17	11	310	9
28 *M. spectabilis*—459.....(849).....	8	8	58	11
29 *M. toringo*.....(851).....	5	5	121	56
30 *M. toringo*.....(853).....	2	2	49	26
31 *M. ringo sublobata*...(854 & 19689).....	19	14	1 825	803
32 *M. prunifolia* var. 5004.....(856).....	3	3	90	38
33 *M.* Yellow Siberian Crab....(857).....	7	5	294	46
34 *M. siberica frutico coccinea*.(19643).....	12	8	513	124
35 *M. microcarpa*.....(19644).....	8	8	609	229
36 *M. scheideckeri*.....(19646).....	16	12	827	202
37 *M. prunifolia* var.....(19651).....	6	5	91	16
38 *M. toringo*.....(852 & 19664).....	15	11	517	130
39 *M. malus* var.....(19667).....	15	9	607	177
40 *M. malus pendula*.. (832 & 19688).....	2	2	22	0
41 *M.* Whitney Crab.....	1	1	50	26
42 *M.* Yellow Siberian Crab.....	9	8	412	1
43 *M.* Florence Crab.....	2	2	90	41
44 *M.* General Grant Crab.....	2	2	94	35
Total.....	320	245	19 676	4 225

dantly available than others; some have flowered regularly since the first year of flower production, while others appear to have the habit of biennial flowering. Some exist only as small potted trees that are forced under glass and produce but few flowers.

Four of the forms on which pollinations were made and which yielded no fruits were *M. baccata* (808), *M. halliana* (823), *M. ioensis fl.pl.* (826), and *M. malus pendula* (832). On an eight-year-old tree of *M. baccata* (808), flowering sparingly for the second time, 135 flowers were supplied with Jonathan pollen in 1915; no fruits resulted altho a few fruits developed from flowers open to insect pollination. Two attempts were made on *M. halliana* (823); the first in 1915 on a potted tree flowering for the first time in the greenhouse and 8 flowers were pollinated with pollen of Yellow Transparent.

In 1916 a tree in orchard flowered for the first time and 106 flowers were pollinated with Oldenburg pollen; in this case no fruits formed on the tree. The attempt on *M. ioensis fl.pl.* (826) was without expectancy of success in view of the extreme fulness of the flowers. The tree used was on a dwarf stock in pot in the greenhouse; 10 flowers were emasculated and pollinated with Yellow Transparent pollen, but neither the protected flowers nor those left open produced any fruits. Multiplication of parts in flowers of this crab is carried to a greater extent than in flowers of any other form examined; petals vary in number from 18 to 28, stamens from 25 to 34, and styles from 9 to 11. The remaining form that failed in fruit production, *M. malus pendula* (832), was also on dwarf stock in the greenhouse; in this case 8 flowers were pollinated by Akin pollen and 14 by Oldenburg pollen. Three other forms narrowly missed entire failure; Yellow Siberian Crab from nine matings with 8 orchard varieties gave only 1 fruit from 412 pollinations; *M. malus* var. (830) from two matings with 2 varieties gave 1 fruit from 94 pollinations, and *M. niedwietzkyana* from nine matings with 7 varieties gave 1 fruit from 290 pollinations. From these low degrees of success there were all grades up to 70 fruits from 77 pollinations, or 90.9 percent for the aggregate of five matings of *M. baccata oblonga* (811) with five different pollen plants. Individual matings to the number of eight were 100 percent successful, but these involved small numbers of pollinations; they were as follows: in the greenhouse, *M. baccata oblonga* (811) X Oldenburg, 3 pollinations; *M. sylvestris fastigiata bifera* (820) X Oldenburg, 5 pollinations; *M. toringo* (19664) *dwarf form* X Grimes, 10 pollinations; *M. malus* var. (19667) X Grimes, 7 pollinations; and by Yellow Transparent, 16 pollinations; in the orchard, *M. prunifolia* (838) X Osimoe, 11 pollinations, and by Ben Davis, 33 pollinations. Considering the group as a whole the aggregate of flowers pollinated was 18,676 and the number of fruits matured, 4,225. The fruits represent 22.62 percent of the flowers pollinated, and this may be compared with 15.83 percent as similarly determined for Group 2, and 12.9 percent for Group 1. The ratios of matured fruits to flowers pollinated in the three groups, are as follows:

Group 1.....1 to 7.74
Group 2.....1 to 6.31
Group 3.....1 to 4.42

Ratios for Groups 2 and 3, in which crab forms serve as pistillate parents in one and as pollen parents in the other, are distinctly higher than the ratio for the group in which both parents in all matings were orchard varieties, and the ratio for Group 3 is decidedly better than that for Group 2. This apparently bears out the statement made on a preceding page that pollen of orchard varieties appears to be more acceptable to stigmas of flowers of crab-like forms than is the pollen of crab-like forms to stigmas of flowers of orchard varieties.

As already stated, apple pollinations in the greenhouse began in 1913; previous to this—that is, in the years 1909, 1911, and 1912, there had been made within Group 3 forty matings with 1,109 pollinations and yielding 427 fruits on trees in orchard. For the last four years the matings in this group under glass have numbered 201, involving pollination of 3,889 flowers, and yielding 1,040 fruits; for the same period the matings in orchard numbered 79, and included 13,678 flowers from which 2,758 fruits matured. Thus while the number of inside matings is considerably larger than the number in orchard, the greater numbers of flowers were pollinated in outside matings on orchard trees. For the greenhouse the average number of flowers in each mating was 19.34, while for the orchard trees the average was 127.64. Only small trees producing small numbers of flowers were available in the greenhouse, while usually the orchard trees flowered abundantly. The ratio of fruits to flowers is higher for pollinations made in the greenhouse than for those made in orchard. In the greenhouse 3.73 flowers were pollinated for each fruit produced, and pollination of 4.68 flowers was required for each fruit produced in orchard. Matings that failed in fruit production aggregate 101 or 31.56 percent of the total made, and they include 3,185, or 17.05 percent, of the flowers pollinated.

As between greenhouse and orchard, 74 of the failures involving 821 flowers pollinated are recorded as occurring in the greenhouse and 27 with 2,364 flowers pollinated on trees in orchard. In a considerable number of cases failure was anticipated or predicted as the result of circumstances attending or observations made at the time of pollination. In some instances pollen was deliberately applied to immature stigmas, while in other instances periods of four to six days were allowed to intervene between emasculation and pollination in an attempt to ascertain the range of receptive maturity and the possibility of effecting fertilization thru immature stigmas. This problem is an important one, but properly has no place in the breeding project as now carried on; it should be taken up as a distinct unit for more extended work than is possible in connection with a predetermined pol-

lination schedule. Injecting it into the line of effort now pursued only serves to increase the number of failures that must form part of the record of the project. It does, however, develop a better understanding of the extent of the investigation necessary for the establishment of a dependable basis for definite conclusions regarding this matter of receptive maturity, which, tho apparently simple, is in reality extremely complex, involving factors of age, environment, physiological functions, ancestry, and in short all agencies affecting plant activities.

Multiplication of floral organs is accepted as the cause of failure with M. *ioensis fl.pl.* (826) and may be the cause of low percentage of success with *M. malus fl.pl.* (833); in this form doubling is not so extreme as in *M. ioensis fl.pl.* (826) and the plant is not wholly sterile. *M. spectabilis* (849) is another form that because of multiplied parts may be classed with the two previously mentioned, but like *M. malus fl.pl.* (833), it is not entirely sterile. Extreme differences between the forms mated—in other words, violence of the cross, may account for failure of several matings of *M. niedwietzkyana* and possibly this same reason can be assigned for ill success with *M. soulardi* (846) and one of the two varieties of Yellow Siberian Crab. *M. niedwietzkyana* was mated with Stayman Winesap, Delicious, Oldenburg, Fanny, Oliver, Yellow Transparent, and Jonathan, in all 290 pollinations, but only one of 18 flowers pollinated with Yellow Transparent developed a fruit. *M. soulardi* was mated seventeen times with 11 varieties and 310 as the total of pollinations; eleven matings with 231 pollinations failed entirely, four with an aggregate of 24 pollinations, gave 1 fruit each, one gave 2 fruits from 49 flowers, and another 3 fruits from 6 flowers. This record shows that *M. soulardi* does not hybridize readily, and gives sufficient reason for the impression that this form is at least unsatisfactory as a mother plant. Yellow Siberian Crab, with 412 pollinations, in nine matings with 8 varieties yielded only 1 fruit from 48 pollinations by Domine. The varieties with which entire failure resulted were Oldenburg, Twenty Ounce, Tolman, Yellow Transparent, Jonathan, Osimoe, and Fanny. Yellow Siberian Crab has an unsatisfactory record that may be due to a general incompatibility between this variety and those with which it was mated, but so far as is indicated by visible characters the crosses attempted are no more violent than were the fifteen matings between *M. malus* var. (19667) and the same and other like varieties, all of which were in some degree successful; or the fifteen matings of *M. prunifolia* (838) with similar varieties, fourteen of which were more or less successful. Other forms of Malus record some failures but only in the three mentioned were they so nearly complete.

Varieties Used as Pollen Parents in Group 3

The orchard varieties used to supply pollen for the matings of Group 3, number 29, in great part were the same as those used as pistillate parents in Group 2. Twenty-five of them were used in both groups, 4 were used in Group 3, but not in Group 2, and 10 were used in Group 2 that do not appear in Group 3. The varieties used are arranged in alphabetical order in Table 15. The number of

TABLE 15.—VARIETIES SUPPLYING POLLEN FOR MATINGS IN GROUP 3, CRAB-LIKE FORMS OF MALUS X ORCHARD VARIETIES

Variety	Number of matings	Number of forms on which used	Flowers pollinated	Fruits matured
1 Akin	9	7	82	21
2 Arkansas	4	4	519	8
3 Beach	2	2	214	10
4 Ben Davis	55	4	592	132
5 Collins	7	6	1 279	542
6 Delicious	12	11	187	111
7 Domine	29	19	1 742	355
8 Fameuse	6	6	234	25
9 Fanny	16	15	364	30
10 Grimes	32	20	1 585	304
11 Isham	2	2	347	99
12 Jonathan	26	22	2 281	443
13 Lady	5	5	85	42
14 Longfield	1	1	533	31
15 Maiden Blush	1	1	14	4
16 Oldenburg	52	29	4 000	794
17 Oliver	11	10	219	72
18 Osimoe	5	4	1 226	256
19 Red Astrachan	3	3	44	6
20 Rome	3	3	75	53
21 Shackleford	6	5	446	120
22 Shockley	2	2	316	44
23 Stayman Winesap	19	17	346	63
24 Summer Pound Royal	1	1	34	16
25 Tolman	2	2	74	23
26 Twenty Ounce	3	3	104	22
27 Winesap	5	5	69	41
28 Winter Rambo	10	9	771	264
29 Yellow Transparent	41	27	894	294
Total	320	245	18 676	4 225

Malus forms on which used is also given together with the flowers pollinated and the fruits matured.

Considering the 320 matings from the side of the male parents, 202 were made in the greenhouse and 118 in orchard. Dividing the 101 failures as to location, 72 of them occurred in the greenhouse and 29 in the orchard; together these failures include 3,283 pollinations, about 17.5 percent, which can not be considered an excessive or unexpected proportion of the whole number of pollinations. Most failures, partic-

ularly those in the greenhouse, involved small numbers of flowers. The larger proportion of flowers to matings in the orchard was due to a few matings in which the numbers of flowers were unusually large and which failed entirely from some undetermined cause, as for example the pollination of 369 flowers of *M. arnoldiana* (802) by Jonathan, 201 flowers of *M. niedwietzkyana* (834) by Jonathan, 286 flowers of *M. baccata* (806) by Grimes, and 202 flowers of *M. floribunda* (821) by Arkansas. These swell the number of pollinations that failed, and with at least three of the mother plants given it is probable that repetition of the combinations would give entirely different results. Failures are shared by twenty of these pollen plants; there are nine varieties used in twenty-four matings for which no complete failures are recorded.

Performance of Some of the Pollen Varieties

Oldenburg was more frequently used for supplying pollen than any other variety. Pollen of this variety was used in 52 matings on 29 of the 44 forms of Malus and pollinated 4,000 flowers which developed 794 fruits. The greenhouse matings number 37, 12 of which, with 162 flowers, failed in fruit production, and of 15 matings on orchard trees, 3, with 195 flowers, failed. The greenhouse matings that failed covered a relatively small number of flowers, an average of only 13.5 to each mating. The three failures in orchard were on two of the Malus forms; one on *M. halliana* (823), with 106 flowers, in 1916, and two on Yellow Siberian Crab, one with 48 flowers in 1909, and one with 41 flowers in 1913. Success with Oldenburg pollen has been so general that it is believed the causes of recorded failures may rightly be ascribed to defects in the pistillate plants, to inability to function in the case of first flowers borne by small trees in greenhouse, to the same cause in the case of *M. halliana* in orchard, and to general infertility on the part of Yellow Siberian Crab, which has already been referred to as infertile with 7 different varieties.

Oldenburg has large anthers, produces viable pollen in abundance, and is regarded as one of the best pollenizers available. Because of the estimation in which this pollen is held it has been more frequently used than any other, has been chosen for extreme and doubtful matings, and hence has a success percentage, as computed from the aggregates of flowers and fruits, slightly lower than the general average for all pollinations.

Yellow Transparent is next to Oldenburg in the number of matings in which used; the record covers 41 matings with 27 forms of Malus; 38 of these were in the greenhouse and only 3 in orchard. Preponderance of inside matings is due to the possession of two potted trees which supplied pollen in the first years of work under glass when other varieties were not available. Of the 38 greenhouse matings, 12

failed to develop fruits as did also one of the 3 matings in orchard. This failure in orchard was the pollination of 43 flowers of Yellow Siberian Crab, which was equally sterile with pollen of 6 other varieties. The greenhouse failures involved 101 flowers, approximately one-ninth of all flowers pollinated by this variety. The aggregate of flowers pollinated was 894, from which 294 fruits developed, giving 32.88 as the percentage of success. This is considerably higher than the percentage for all varieties, which is 22.62. Some of the higher degrees of success attained by pollen of Yellow Transparent were on *M. baccata oblonga* (811), where 49 flowers gave 48 fruits, or were 97.96 percent successful, on *M. ringo* (840), where 27 flowers gave 25 fruits, or were 92.57 percent successful, on *M. sargenti* (843) where 11 flowers gave 10 fruits, or were 90.91 percent successful, on *M. malus* var. (19667) where 2 matings, one of 9, the other of 7 flowers, were 100 percent successful. Yellow Transparent is rated equal to Oldenburg in abundance and vitality of its pollen.

Domine was used as a pollenizer in 29 matings with 19 different forms of Malus. The total of flowers pollinated was 1,742, and of the fruits matured, 355; this gave a success percentage of 20.37. The division of matings between greenhouse and orchard was 13 for the greenhouse and 16 for the orchard. All matings in the orchard were in some degree successful, percentages ranging from 2.08 percent for one fruit from 48 pollinations of Yellow Siberian Crab flowers to 82.35 percent for 28 fruits from 34 flowers of *M. prunifolia* (838). The success percentage from the aggregates of pollinations in orchard was 21.50. Four of the 13 greenhouse matings with 81 flowers failed; the 9 matings producing fruit had a range of success percentages from 6.82 for 3 fruits from 44 pollinations of flowers of *M. floribunda* (821) to 69.23 percent for 9 fruits from 13 pollinations of flowers of *M. ringo* (840); because of the four failures the success percentage of greenhouse pollinations fell to 13.78. Domine pollen may be said to have been highly acceptable to stigmas of flowers of *M. prunifolia* var. (838), to *M. ringo* (840), and to *M. toringo,* dwarf form (19664); reasonably acceptable to *M. sylvestris fastigiata bifera* (820), to *M. baccata maxima* (810), to *M. atrosanguinea* (804), and to *M. dioica* (819); much less acceptable to *M. floribunda* (821), and to *M. prunifolia xanthocarpa* (839); and to have been refused by *M. malus* var. (830), by *M. microcarpa* (19644), by one of 2 matings with *M. prunifolia xanthocarpa* (839), and by one of 2 matings with *M. prunifolia* var. (19651).

However, it must be remembered that in all cases of refusal of pollen and of low percentages of success the condition of the pistillate parent or of the pistils themselves constitutes an important factor and may have been such as to absolve the pollen parent from any suspicion of deficiency. There is abundant evidence that the relation of any

particular pollen plant to any particular pistillate plant is inconstant, varying greatly with seasonal and physiological factors, and any definite conclusion as to the desirability of a plant or variety as a pollenizer for another must rest upon a much greater number of matings than are here under consideration. Domine pollen falls readily from the anthers, is powdery, of high vitality, and the variety is given place as a desirable pollenizer, but statement of its virtue for use on a particular variety or form of Malus must be held in abeyance pending more extended trials.

Grimes was used in 32 matings on 20 different forms of Malus; there were 1,585 pollinations, which matured 304 fruits. Greenhouse matings numbered 21 with 219 flowers and 61 fruits, those in orchard numbered 11 with 1,366 flowers and 243 fruits. Failures recorded include seven with 57 flowers for greenhouse and three with 464 flowers for orchard. The ratios of fruits to flowers pollinated were, for greenhouse pollinations 1 to 3.59, for pollinations in orchard 1 to 5.62, or for the aggregate of all, 1 fruit for each 5.21 flowers pollinated. As with other varieties the greenhouse pollinations involved small numbers of flowers, an average of about 10.5 to each mating, while the average for trees in orchard was a fraction over 124 flowers to each mating. Success percentages for the different matings had a rather wide range from a fraction of 1 percent for 257 pollinations on *M. ringo,* in the orchard, which yielded 1 fruit, to 100 percent for 2 matings under glass, one of 10 flowers on *M. toringo* (19664), and the other of 7 flowers on *M. malus* var. (19667). Grouping all matings in the greenhouse, the success percentage was 27.85, for those in orchard, 17.78, and for the aggregate without reference to location, 19.18 percent.

Grimes is regarded as a good pollenizer and for most cases of failure and low percentages of success appearing in this record the cause is believed to rest with the pistillate parent.

Jonathan is very similar to Grimes, as may be seen by its record, and the two are held in equal estimation as pollen parents. Jonathan was mated twenty-six times with 22 different forms of Malus. The number of flowers pollinated was 2,281, and 443 fruits were matured. The percentage of success was 19.42, which differs but little from that attained by Grimes.

Seed Production and Distribution in Group 3

Fruits matured from the crosses of Group 3 total 4,225 and the aggregate of seeds saved was 20,179, or an average of 4.77 seeds to each fruit. In assembling the records for examination of seed production it was found that for three of the Malus forms the totals included some fruits that did not have complete seed records; they were fruits that had been invaded by codling moth larvæ and the cores eaten to such extent that no accurate record of seeds was possible, or that thru

some other cause had incomplete seed records. Such apparently good seeds as were found in these fruits were saved, but there was no way of determining either distribution or full number produced. Because of the incomplete record, these fruits and the seeds they produced are not included in the tabulated seed-production records. The forms affected and the number of fruits and seeds eliminated were as follows:

M. baccata oblonga (811)—17 fruits with 107 seeds
M. prunifolia var. (838)—73 fruits with 310 seeds
M. toringo (19664)—18 fruits with 26 seeds

Adding these various numbers and deducting from the total leaves 4,117 fruits and 19,736 seeds to be included in the distribution tabulation, giving an average of 4.79 seeds to each fruit. Recalling the average, 7.05 seeds to each fruit, as determined for Group 1, and that of 7.14 seeds to each fruit as found for Group 2, it appears that Group 3, in which the pistillate parents were all crab-like forms of Malus, had a very much lower average seed production than had either of the groups in which the pistillate parents were orchard varieties. The average of 4.79 seeds to each fruit is, however, distinctly higher than the average 3.78 seeds to each fruit as found for 5,007 naturally fertilized fruits of 22 crab-like forms of Malus as reported in Bulletin 203.

The range in seed production, as appears in Table 16, is 0 to 16, with only 1 fruit of one of the forms of *M. spectabilis* reaching the maximum; the number next below the maximum, 12 seeds to the fruit, is reached in 1 fruit of the same form that contains the maximum and also in 4 fruits of *M. baccata maxima* (810); the next number lower, 11 seeds to each fruit, is represented by 1 fruit each of 4 different forms of Malus, and in the column for 10 seeds to each fruit, which is taken as the normal content for apples, there appear 107 fruits distributed among 15 of the Malus forms in numbers from 1 to 30. There were thus 117 fruits, or 2.84 percent of the total, that reached normal or above in seed production. The highest frequency falls at 4 seeds to each fruit, with a representation in this column of 538 fruits, or 13.06 percent of the total, distributed among 33 of the 45 Malus forms. Numbers in the four columns representing 2, 3, 4, and 5 seeds to each fruit are very nearly equal and aggregate 2,110 fruits, or 51.25 percent of all fruits. Parthenocarpic fruits number 46 and represent 14 forms in numbers from 1 to 22; 5 forms each have 1 such fruit, 6 forms have 2 each, 1 has 3, 1 has 4, and *M. ringo sublobata* (854) has 22, which is 2.73 percent of the 803 fruits of this form. Fruits producing 1 seed each number 353 and are distributed among 27 forms of Malus in numbers from 1 to 70. Four of the 44 forms of Malus are not represented by fruits, and of the 40 fruiting kinds 8 are represented by less than 10 fruits each, and 25 have less than 100 fruits each, so that for a large proportion of the fruiting forms there is insufficient basis from which to judge their possibilities in seed-production accurately.

TABLE 16.—DISTRIBUTION OF SEEDS IN HYBRID FRUITS OF GROUP 3, CRAB-LIKE FORMS OF MALUS X ORCHARD VARIETIES

Species or variety	Number of parental combinations	Number of fruits	Number of seeds	Average number of seeds to fruit	Seeds to each fruit															
					0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1 *M. arnoldiana* (802)	5	108	424	3.92	...	6	19	26	18	17	12	8	1	1	...	...	...	...	...	...	...
2 *M. atrosanguinea* (804)	7	57	89	1.56	1	35	14	2	5	...	...	...	...	...	...	...	...	...	...	...	...
3 *M. baccata*, red fruit (806)	4	201	1 483	7.37	...	1	7	2	11	13	26	30	42	39	30	...	...	...	...	...	...
4 *M. baccata*, red fruit, late (807)	5	253	1 043	4.12	1	7	37	52	55	38	48	12	3	...	...	...	...	...	...	...	...
5 *M. baccata* var (808)	1	0	.....	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
6 *M. baccata maxima* (810)	5	316	2 158	6.83	...	...	7	12	15	48	54	55	58	44	18	1	4	...	...	...	...
7 *M. baccata oblonga* (811)	5	53	357	6.74	2	...	...	...	2	12	6	10	11	5	5	...	...	...	...	...	...
8 *M. baccata* var. *sieboldi* (814)	2	100	734	7.34	...	...	...	1	3	9	22	17	21	16	10	1	...	...	...	...	...
9 *M. coronaria* (818)	5	5	16	3.20	...	...	1	3	...	1	...	...	...	...	...	...	...	...	...	...	...
10 *M. dioica* (819)	5	14	67	4.78	...	1	1	2	2	4	1	1	1	1	...	...	...	...	...	...	...
11 *M. sylvestris fastigiata* (820)	11	121	661	5.47	...	2	9	11	13	26	19	23	12	5	1	...	...	...	...	...	...
12 *M. floribunda* (821)	11	138	391	2.83	3	31	28	25	31	16	3	1	...	...	...	...	...	...	...	...	...
13 *M.* Fluke Apple (822)	4	5	17	3.40	...	...	...	3	2	...	...	...	...	...	...	...	...	...	...	...	...
14 *M. halliana* (823)	2	0	.....	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15 *M.* Ilyslop Crab (824)	3	57	257	4.51	1	3	3	9	9	18	6	5	3	...	...	...	...	...	...	...	...
16 *M. ioensis* (825)	2	65	349	5.37	...	4	6	5	8	11	11	4	10	3	3	...	...	...	...	...	...
17 *M. ioensis fl. pl.* (826)	1	0	.....	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
18 *M. malus* var (830)	2	1	6	6.00	...	...	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...
19 *M. malus fl. pl.* (833)	1	10	72	7.20	...	...	...	...	1	3	...	1	2	1	1	1	...	...	...	...	...
20 *M. niedwietzkyana* (834)	7	1	4	4.00	...	...	...	...	1	...	...	...	...	...	...	...	...	...	...	...	...
21 *M. prunifolia macrocarpa* (837)	6	8	28	3.50	...	2	1	1	1	2	...	1	...	...	...	...	...	...	...	...	...
22 *M. prunifolia* var (838)	13	348	1 926	5.54	2	24	47	28	38	26	29	45	42	54	12	1	...	...	...	...	...
23 *M. prunifolia xanthocarpa* (839)	2	4	4	1.00	...	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
24 *M. ringo* (840 & 19662)	11	188	1 078	5 73	...	7	11	16	18	23	36	37	25	11	4	...	...	...	...	...	...
25 *M. fusea* (841)	1	11	14	1.27	...	8	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...
26 *M. sargenti* (843)	8	101	222	2.18	4	26	32	25	13	1	...	...	...	...	...	...	...	...	...	...	...
27 *M. soulardi* (846)	11	9	17	1.88	2	2	...	5	...	...	...	...	...	...	...	...	...	...	...	...	...
28 *M. spectabilis* (849)	8	11	78	7.09	1	...	...	1	...	3	1	1	...	1	1	...	1	...	...	...	1
29 *M. toringo* (851)	5	56	158	2.82	2	16	9	11	6	8	2	1	1	...	...	...	...	...	...	...	...
30 *M. toringo* (853)	2	26	99	3.81	...	1	4	6	6	3	...	...	...	...	...	...	...	...	...	...	...
31 *M. ringo sublobata* (854 & 19689)	14	803	2 901	3.61	22	70	153	155	159	116	71	42	11	4	...	...	...	...	...	...	...
32 *M. prunifolia* var (856)	3	38	264	6.95	...	...	...	1	1	3	9	10	9	4	1	...	...	...	...	...	...
33 *M.* Yellow Siberian Crab (857)	5	46	267	5.80	...	2	1	6	5	5	7	9	7	1	3	...	...	...	...	...	...
34 *M. siberica frutico coccinea* (19643)	8	124	828	6.67	...	1	1	5	12	12	22	26	21	20	4	...	...	...	...	...	...
35 *M. microcarpa* (19644)	8	229	1 594	6.96	...	1	1	2	15	27	36	58	46	30	13	...	...	...	...	...	...
36 *M. scheideckeri* (19646)	12	202	462	2.28	2	61	64	46	16	9	2	2	...	...	...	...	...	...	...	...	...
37 *M. prunifolia* var (19651)	5	16	55	3.44	1	1	3	2	5	2	2	...	...	...	...	...	...	...	...	...	...
38 *M. toringo* (19664)	11	112	273	2.44	2	25	36	27	16	5	1	...	...	...	...	...	...	...	...	...	...
39 *M. malus* var (19667)	9	177	757	4.29	...	11	19	28	35	44	23	12	3	2	...	...	...	...	...	...	...
40 *M. malus pendula* (832 & 19688)	2	0	.....	....	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
41 *M.* Whitney Crab	1	26	135	5.19	...	...	1	2	8	6	3	3	1	2	...	...	...	...	...	...	...
42 *M.* Yellow Siberian Crab	8	1	9	9.00	...	...	...	...	...	...	...	...	...	1	...	...	...	...	...	...	...
43 *M.* Florence Crab	2	41	226	5.51	...	...	6	1	6	5	10	5	5	3	...	...	...	...	...	...	...
44 *M.* General Grant Crab	2	35	213	6.08	...	1	...	4	2	4	7	10	4	2	1	...	...	...	...	...	...
Total	245	4 117	19 736	4.79	46	353	524	525	538	523	473	429	339	250	107	4	5	...	...	...	1

Period of Fruit Maturity

The period of fruit harvest for hybrids of Group 3 extended from June 2 to October 31. Pollinations in the greenhouse were begun February 26 and continued until March 21; descriptions of resulting fruits were begun June 2 and ended September 28. The first fruits maturing were those of *M. dioica,* from pollinations of February 26 and 28, which were described June 2 and 7; next following were fruits of *M. spectabilis* (849), described June 22, and then *M. sylvestris fastigiata bifera* (820), July 10. Others matured at intervals until the last fruits of *M. soulardi* and *M. ioensis* were described September 28. From orchard pollinations early in May the first fruits maturing were those of *M. baccata sieboldi* (814), *M. baccata maxima* (810), *M. prunifolia macrocarpa* (837), and Florence Crab, all of which were described August 17-19; then follow *M. sylvestris fastigiata bifera* (820), on September 1; *M. siberica frutico coccinea* (19643), *M. malus* var. (830), Hyslop Crab, and General Grant Crab, September 11 to 15; *M. microcarpa,* September 25, and finally others of the *baccata* group, the forms of *M. prunifolia, M. floribunda,* and its allies *M. atrosanguinea* and *M. arnoldiana,* and the forms of *M. toringo* with which may be classed *M. sargenti,* and last of all *M. ioensis;* these extended the season of fruit description to the last of October. With the forms last mentioned there is much latitude in regard to time for harvesting. Usually the fruits are fully colored by October 1 and are ready to pick at any time between that date and the first killing frost.

Loss of Seeds Between Extraction and Planting

The seeds saved from the 4,225 fruits number 20,179; there were planted 19,743, showing a loss of 436 seeds in the period between extraction and planting, or 2.15 percent of the number saved. This is a much smaller percentage of loss than is recorded for either of the other groups considered; for Group 2 the loss percentage is more than twice as large as for Group 1 and more than three and one-half times as large as for Group 3. Storage periods were not materially different for seeds of the different groups; for Group 3 the periods were, for seeds from fruits from greenhouse pollinations 69 to 187 days, and for seeds from fruits from orchard pollinations 36 to 117 days.

The seeds of Group 3 were produced by 214 matings, and of these 136 showed no loss, the number saved and the number planted being in each case the same; the losses were then distributed among 78 matings, in 24 of which the loss was but one seed each. The largest loss occurred in a mating of *M. prunifolia* var. (838) with Rome, in which 31 fruits contained 246 seeds, only 207 of which were planted, a loss of 39 seeds; next to this was a loss of 30 seeds in the mating General Grant Crab with Domine. One mating lost 28 seeds, one, 24, another, 22; beyond this the losses were less than 20 and mostly very

small. The seed losses in this group were small, no larger than was to be expected, and need no further comment.

Percentage of Germination Lower in Group 3 Than in Other Groups

Seeds planted from the hybrid fruits of Group 3 numbered 19,743; of these 10,857, or 54.99 percent, are recorded as having germinated (Table 17). This percentage is decidedly lower than for the other groups; for Group 1, 62.22 percent germinated and for Group 2, 71.99 percent. Examination of percentages of germination for individual

TABLE 17.—NUMERICAL RELATION OF LIVING SEEDLINGS TO SEEDS GERMINATED IN GROUP 3, CRAB-LIKE FORMS OF MALUS X ORCHARD VARIETIES, WITH PERCENTAGES AND AGES OF TREES

Year	Number of matings	Seeds germinated	Seedlings living		Age of trees, *yrs.*
			Number	Percentage	
1909	1	7	6	85.71	7
1911	4	35	13	37.14	5
1912	23	1 151	731	63.51	4
1913	11	576	329	57.11	3
1914	46	1 982	1 068	53.88	2
1915	26	2 132	1 780	83.48	1
1916	66	4 974	4 298	86.40	¼
Total	177	10 857	8 225	75.77	....

matings does not disclose any definite reason why the general average of the group was below that of other groups. For a large proportion of the matings the germination was fairly good, and in some it was high. In four matings all seeds germinated, but the numbers of seeds were small; in three, the percentage is above 90, and twelve other matings have percentages ranging between 80 and 90. The group giving least satisfactory results is that of *M. sargenti;* this species was the pistillate parent in eleven matings with eight different pollen plants; two produced no fruits; seven of the nine yielding fruits had a total of 182 seeds, all of which failed to germinate. *M. sargenti* X Grimes produced 21 seeds, 12 of which, or 57.14 percent, germinated, and *M. sargenti* X Yellow Transparent produced 18 seeds, only 1 of which germinated. Brief mention may be made here of the performance of some of the groups of crosses having the largest numbers of seeds. *M. prunifolia* var. (838) from fifteen matings with 13 orchard varieties produced 1,611 seeds that were planted, of which 1,295, or 80.38 percent, germinated; *M. ringo* from twenty-seven matings with 11 orchard varieties had 1,075 seeds planted, 656 of which, or 61.02 percent, germinated; *M. baccata maxima* (810) from eight matings with 5 varieties produced 2,152 seeds that were planted, 1,548, or 71.93 percent, of which germinated. *M. flori-*

bunda (821) from fourteen matings with 11 varieties gave 368 seeds and germinated 197, or 53.53 percent, and *M. arnoldiana* (802) from seven matings with 5 varieties produced 420 seeds, 289, or 68.81 percent, of which germinated. Aside from the matings of *M. sargenti,* already referred to, in which only 13 of 221 seeds, or 5.88 percent, germinated, there are no groups with such low percentages as to attract attention or need special comment.

Hybrid Seedlings Now Living

Hybrid seedlings resulting from pollination of flowers of the various crab-like forms of Malus by pollen of orchard varieties in the years 1909 and 1911-1915 numbered, late in the fall of 1916, 3,927, and to these may now be added the seedlings grown from seeds of fruits developed from the pollinations of 1916. These seedlings were planted in nursery about three months ago and have been recently enumerated in order to eliminate any that died in the interval since planting. Growing conditions have been unusually favorable, losses have been very small, and the living seedlings are exhibiting a degree of vigor above the experience of most seasons. These young seedlings number 4,298, and represent 86.4 percent of the number recorded in the record of germination; adding these to the seedlings of preceding years gives 8,225 as the total of living seedlings in Group 3; they represent 177 distinct matings and 142 different combinations of parent plants.

The numbers of seedlings under the different combinations of parents varies between 1 and 990; there are 18 combinations each represented by one seedling, 20 that have two seedlings each, 41 that have each about 50, and *of these* 20 have above 100 seedlings each. Naturally the larger groups are among those that have been exposed, for the shortest periods of time, to accidents and to the influences that combine to eliminate weak individuals, but among the seedlings of 1912 are six groups with more than 50 each, and two have above 100. All seedlings to and including those of 1914 have been planted in orchard, while the others are in nursery. Distribution of the seedlings by years, with percentages and age, are given in Table 17.

Detailed Performance of Some Crab-like Forms on Which Pollen of Orchard Varieties Was Used

Behavior of a few of the Malus forms that have been most freely used may here be given in detail to show their reaction to pollen of orchard varieties.

M. prunifolia var. (838).—Because of its prolificacy, this variety has been somewhat of a favorite; it flowers and fruits regularly and abundantly, and has served as the pistillate parent in fifteen matings; four in orchard in 1911, seven in orchard in 1912, two in greenhouse and one in orchard in 1914, and one in orchard in 1915.

One of the matings of 1912 repeated one of 1911, and the one in orchard in 1914 repeated a mating of 1912, so that the fifteen matings represent 13 distinct combinations of parents. With the one exception of the pollination of nine flowers with pollen of Stayman Winesap, in the greenhouse in 1914, all matings produced fruits ranging in numbers from 3 for the cross with Arkansas to 142 for the cross with Collins.

The aggregate of flowers pollinated was 770 and of fruits matured 421, a success percentage of 54.67, and a ratio of one fruit for each 1.82 flowers pollinated. There were 2,236 seeds saved from the 421 fruits, an average of 5.31 from each fruit; the number of seeds planted was 2,111, showing a loss of 125 seeds, or 5.59 percent, in the interval of dry storage between extraction and planting. Of the 2,111 seeds planted 1,295, or 61.34 percent, are recorded as having germinated. Seedlings living at ages from one to five years number 899 and represent 69.42 percent of those appearing in the germination record. An apparent discrepancy in numbers of fruits and seeds may be referred to and explained here. In the tabulation of seed distribution for the forms of Malus, this variety appears as having but 348 fruits and 1,926 seeds, while in this detailed account of the variety the number of fruits is given as 421 and the number of seeds as 2,236. This difference arises from the fact that 73 fruits had no record of seed distribution and hence they and the 310 seeds they produced were omitted from the tabulation. The actual production for the variety was 421 fruits and 2,236 seeds (Table 18).

M. ringo sublobata (854 and 19689).—This variety was used as the pistillate parent in nineteen matings with 14 different orchard varieties (Table 19). Five matings are duplicated, four in different years; one pollen variety, Collins, was used twice in one year, but the matings were on different trees and so are listed separately. Nine of the matings were on trees in orchard and ten were made in the greenhouse; those made under cover were limited in numbers of flowers by the youth and size of available trees, and the same is true of the 1912 matings in orchard. For orchard matings in later years bloom was abundant and the numbers of flowers utilized were easily increased. Six matings which together represented 70 pollinations failed entirely; two of these were in 1912 on an orchard tree flowering for the first time and failure was ascribed to imperfections in the flowers; the other four were greenhouse matings, two with Yellow Transparent, one with Grimes and one with Fanny, and nothing is known of the cause of failure. Considering all matings, including those that failed entirely, it appears that 44 percent of the pollinations were successful; this is nearly double the percentage for the group and compared with the percentage for the aggregate of apple pollinations may be regarded as high. Seed production for this variety is low; the average number of seeds for each fruit is 3.61 as compared with an average of 4.79 for

TABLE 18.—PERFORMANCE OF *Malus prunifolia* var. (838) POLLINATED BY THIRTEEN ORCHARD VARIETIES

M. prunifolia var. X	Year	Flowers pollinated	Fruits matured	Percentage of success	Number of seeds			Percentage germinated	Seedlings living
					Saved	Planted	Germinated		
1 Yellow Transparent	1911	41	30	73.17	139	139	7	5.04	1
2 Twenty Ounce	1911	21	13	61.91	37	37	8	21.62	2
3 Domine	1911	25	19	76.00	77	77	10	12.98	4
4 Osimoe	1911	11	11	100.00	57	57	10	17.54	6
5 Arkansas	1912	31	3	9.68	7	6	2	33.33	1
6 Domine	1912	34	28	82.35	228	224	171	76.34	103
7 Oldenburg	1912	34	31	91.17	207	179	121	62.01	65
8 Tolman	1912	24	23	95.83	170	162	105	64.81	65
9 Ben Davis	1912	33	33	100.00	276	252	192	76.19	123
10 Rome	1912	33	31	93.94	246	207	142	68.59	94
11 Grimes	1912	25	19	76.00	146	132	96	72.73	62
12 Delicious	Gh. 1914	14	11	78.57	80	79	62	78.48	48
13 Stayman Winesap	Gh. 1914	9	0	.....	.....	.....	.....	.....	...
14 Grimes	1914	77	27	35.07	124	121	97	80.16	76
15 Collins	1915	358	142	39.67	442	439	272	61.96	249
Total	.....	770	421	54.67	2 236	2 111	1 295	61.34	899

TABLE 19.—PERFORMANCE OF *Malus ringo sublobata* POLLINATED BY FOURTEEN ORCHARD VARIETIES

M. ringo sublobata X	Year	Flowers pollinated	Fruits matured	Percentage of success	Number of seeds			Percentage germinated	Seedlings living
					Saved	Planted	Germinated		
1 Rome	1912	16	8	50.00	36	31	17	54.84	11
2 Ben Davis	1912	12	0	.....	.....	.....	.....	.....	...
3 Winter Rambo	1912	10	0	.....	.....	.....	.....	.....	...
4 Stayman Winesap	Gh. 1914	27	8	29.63	19	18	6	33.33	2
5 Delicious	Gh. 1914	28	23	82.14	95	93	36	38.71	15
6 Shackleford	1914	83	20	24.08	66	65	32	49.08	27
7 Oldenburg	1914	238	58	24.37	193	189	96	50.79	62
8 Yellow Transparent	Gh. 1915	10	0	.....	.....	.....	.....	.....	...
9 Winter Rambo	1915	299	162	54.84	332	331	64	19.03	49
10 Grimes	Gh. 1916	5	0	.....	.....	.....	.....	.....	...
11 Oldenburg	Gh. 1916	43	19	44.19	56	55	24	43.63	21
12 Yellow Transparent	Gh. 1916	19	0	.....	.....	.....	.....	.....	...
13 Jonathan	Gh. 1916	38	16	42.11	50	47	9	19.14	7
14 Oliver	Gh. 1916	82	52	63.41	161	159	41	25.78	35
15 Lady	Gh. 1916	28	19	67.86	43	42	11	26.19	10
16 Fanny	Gh. 1916	14	0	.....	.....	.....	.....	.....	...
17 Ben Davis	1916	288	72	25.00	327	323	130	40.24	123
18 Collins	1916	261	179	68.58	710	707	288	40.73	274
19 Collins	1916	324	167	51.54	813	791	314	39.69	302
Total	.....	1 825	803	44.00	2 901	2 851	1 068	.....	938

TABLE 20.—PERFORMANCE OF *Malus floribunda* POLLINATED BY ELEVEN ORCHARD VARIETIES

M. floribunda X	Year	Flowers pollinated	Fruits matured	Percentage of success	Number of seeds			Percentage germinated	Seedlings living
					Saved	Planted	Germinated		
1 Winter Rambo	1912	44	4	9.09	12	12	8	66.67	5
2 Fameuse	1912	49	14	28.57	46	36	10	27.78	6
3 Grimes	1912	62	4	6.45	14	13	8	61.53	5
4 Domine	1912	44	3	6.82	8	8	3	37.50	0
5 Jonathan	1913	98	0	.....	.....	.....	.....	.....	...
6 Fanny	1913	89	0	.....	.....	.....	.....	.....	...
7 Domine	Gh. 1914	44	3	6.82	8	8	4	50.00	2
8 Arkansas	1914	202	0	.....	.....	.....	.....	.....	...
9 Yellow Transparent	Gh. 1915	3	0	.....	.....	.....	.....	.....	...
10 Domine	1915	354	46	12.99	159	148	79	53.38	53
11 Osimoe	1915	331	27	8.16	91	91	52	57.25	41
12 Oldenburg	Gh. 1916	36	0	.....	.....	.....	.....	.....	...
13 Osimoe	1916	331	6	1.81	9	9	7	77.77	7
14 Longfield	1916	533	31	5.82	44	43	26	60.46	23
Total	.....	2 220	138	6.21	391	368	197	53.53	142

the group to which the variety belongs, or with the average of 5.31 seeds for the variety of *M. prunifolia* previously considered.

M. floribunda (821).—As an illustration of the performance, when pollinated by orchard varieties, of one of the species producing very small fruits, the record of *M. floribunda* may be given.

Flowers of this species were pollinated by 11 orchard varieties in fourteen matings distributed over five years. One mating in each of the years 1914, 1915, and 1916 was made in the greenhouse, all others were on trees in orchard. Two of the inside matings, those with Yellow Transparent and Oldenburg, failed as did also the orchard matings with Jonathan, Fanny, and Arkansas. Such fruits as were borne were the product of nine matings with six varieties. Percentages of success were low for all matings; the highest was for the mating with Fameuse in 1912, which was 28.57 percent, and the lowest for a fruit-producing mating was the 1916 mating with Osimoe, in which 331 flowers pollinated yielded six fruits, or 1.81 percent (Table 20). For all pollinations the success percentage was 6.21; in other words it required the pollination of approximately 16 flowers to produce one fruit. *M. floribunda* is, perhaps, the most difficult to pollinate successfully of any form of Malus in the collection. Buds are so small and the stamens so closely associated with the pistil that extreme care in emasculating is necessary to avoid injury to styles or ovary. It is probable that failures and low percentages of success were, in no small part, due to injuries inflicted at time of emasculation.

GROUP 4: CRAB-LIKE FORMS OF MALUS X CRAB-LIKE FORMS OF MALUS

This group of hybrids is much smaller than the other groups, chiefly for the reason that attention has naturally centered upon those groups in which the combinations of parents included established and well-known varieties. Where one or both of the plants combined already possess qualities giving them economic standing, the possibilities seem greater that the progeny may, thru some readjustment of the aggregate of good qualities, exhibit improvement over either parent, than in combinations between plants having little or no economic value. Plant improvement is a principal aim in breeding, and it is logical to follow that procedure which in the judgment of the breeder offers the best opportunities for successful accomplishment of the end in view. But from the standpoint of a study of character transmission hybrids of Group 4 are no less interesting, no less important than hybrids of the preceding groups; there is even the possibility that combinations of these very diverse forms may prove to be of more value than any of the combinations involving what are conventionally referred to as highly developed varieties — varieties that, in some unexplained manner, have become possessed of qualities that make

TABLE 21.—GROUP 4, CRAB-LIKE FORMS OF MALUS X CRAB-LIKE FORMS OF MALUS

	Female parent	Male parent	Year	Flowers pollinated	Fruits picked	Percentage of success	Number of seeds				Trees living	Percentage of trees from germinations
							Saved	Planted	Germinated	Percent germinated		
1	*M. baccata*.....(806)	*M.* Yellow Siberian Crab.....	Gh. 1914	28	6	21.43	25	23	6	26.09	3	50.00
2	*M. baccata*.....(806)	*M. baccata maxima*.....(810)	Gh. 1916	12	0	.....	.....	.....	...	.....	...	.....
3	*M. baccata maxima*.....(810)	*M. baccata*.....(806)	Gh. 1916	5	0	.....	.....	.....	...	.....	...	.....
4	*M. baccata oblonga*.....(811)	*M. prunifolia xanthocarpa*....(839)	Gh. 1916	11	1	9.09	1	1	0	.....	...	.....
5	*M. baccata oblonga*.....(811)	*M. baccata maxima*.....(810)	Gh. 1916	21	7	33.33	14	14	0	.....	...	.....
6	*M. dioica*.....(819)	*M. halliana*.....(823)	Gh. 1915	5	3	60.00	0	.....	...	.....	...	.....
7	*M. dioica*.....(819)	*M. prunifolia xanthocarpa*....(839)	Gh. 1916	5	3	60.00	19	18	2	11.11	2	100.00
8	*M.* Fluke Apple.....(822)	*M. niedwietzkyana*.....(834)	Gh. 1916	11	0	.....	.....	.....	...	.....	...	.....
9	*M.* Hyslop Crab.....(824)	*M. prunifolia xanthocarpa*....(839)	Gh. 1914	5	1	20.00	6	6	1	16.67	0	.....
10	*M.* Hyslop Crab.....(824)	*M. ringo*.....(840)	Gh. 1914	26	0	.....	.....	.....	...	.....	...	.....
11	*M. malus* var.....(830)	*M.* Yellow Siberian Crab.....(857)	Gh. 1914	18	12	66.67	97	97	54	55.67	34	62.96
12	*M. malus* var.....(830)	*M. prunifolia* var.....(19651)	Gh. 1914	8	2	25.00	15	15	14	93.33	8	57.14
13	*M. prunifolia macrocarpa*.....(837)	*M. siberica frutico coccinea*..(19643)	Gh. 1913	43	15	34.88	106	106	88	83.02	33	37.50
14	*M. prunifolia macrocarpa*.....(837)	*M. baccata maxima*.....(810)	Gh. 1915	7	3	42.86	.....	.....	...	.....	...	.....
15	*M. prunifolia macrocarpa*.....(837)	*M. prunifolia xanthocarpa*....(839)	Gh. 1916	11	0	.....	.....	.....	...	.....	...	.....
16	*M. prunifolia macrocarpa*.....(837)	*M. niedwietzkyana*.....(834)	Gh. 1916	13	0	.....	.....	.....	...	.....	...	.....
17	*M. prunifolia* var.....(838)	*M.* Whitney.....	Orch. 1911	17	10	58.82	35	25	5	20.00	2	40.00
18	*M. prunifolia* var.....(838)	*M.* Yellow Siberian Crab.....	Orch. 1911	37	23	62.16	109	109	3	2.75	3	100.00
19	*M. prunifolia* var.....(838)	*M. niedwietzkyana*.....(834)	Gh. 1914	6	4	66.67	20	20	10	50.00	9	90.00
20	*M. prunifolia* var.....(838)	*M. toringo*.....(853)	Orch. 1911	11	4	36.36	16	16	1	6.25	0	.....
21	*M. prunifolia xanthocarpa*....(839)	*M. malus* var.....(830)	Gh. 1914	12	4	33.33	6	6	0	.....	...	.....
22	*M. soulardi*.....(846)	*M. niedwietzkyana*.....(834)	Gh. 1914	15	0	.....	.....	.....	...	.....	...	.....
23	*M. soulardi*.....(846)	*M. malus* var.....(19667)	Gh. 1916	5	0	.....	.....	.....	...	.....	...	.....
24	*M. spectabilis*.....(849)	*M. prunifolia xanthocarpa*....(839)	Gh. 1914	12	2	16.67	21	21	8	38.09	6	75.00
25	*M. spectabilis*.....(849)	*M.* Whitney.....	Gh. 1914	8	0	.....	.....	.....	...	.....	...	.....
26	*M. toringo*.....(853)	*M.* Hyslop Crab.....(824)	Gh. 1914	15	10	66.67	32	32	26	81.25	3	11.53
27	*M.* Yellow Siberian Crab.....(857)	*M. malus* var.....(830)	Gh. 1914	5	0	.....	.....	.....	...	.....	...	.....
28	*M.* Yellow Siberian Crab.....(857)	*M. prunifolia* var.....(19651)	Gh. 1916	13	2	15.38	5	5	1	20.00	1	100.00

TABLE 21.—*Concluded*

	Female parent	Male parent	Year	Flowers pollinated	Fruits picked	Percentage of success	Number of seeds				Trees living	Percentage of trees from germinations
							Saved	Planted	Germinated	Percent germinated		
29	*M. siberica frutico coccinea*..(19643)	*M. sargenti*.....(843)	Gh. 1914	13	8	61.54	48	48	6	12.50	2	33.33
30	*M. siberica frutico coccinea*..(19643)	*M. niedwietzkyana*.....(834)	Gh. 1916	24	15	62.50	106	106	65	61.32	59	90.77
31	*M. siberica frutico coccinea*..(19643)	*M. microcarpa*.....(19644)	Gh. 1916	16	10	62.50	67	67	30	44.77	23	76.66
32	*M. microcarpa*.....(19644)	*M.* Whitney.....	Gh. 1914	25	10	40.00	57	57	17	29.82	5	29.41
33	*M. microcarpa*.....(19644)	*M.* Yellow Siberian Crab.....(857)	Gh. 1916	11	1	9.09	9	9	1	11.11	1	100.00
34	*M. scheideckeri*.....(19646)	*M.* Whitney.....	Gh. 1915	12	4	33.33	7	7	3	42.86	2	66.67
35	*M. prunifolia* var.....(19651)	*M. prunifolia xanthocarpa*....(839)	Gh. 1914	36	10	27.78	27	26	11	42.31	5	45.45
36	*M. prunifolia* var.....(19651)	*M. baccata* var.....(806)	Gh. 1914	20	0	.....	.....	.....	...	.....	...	.....
37	*M. prunifolia* var.....(19651)	*M. malus* var.....(830)	Gh. 1914	25	5	20.00	16	16	14	87.50	10	71.42
38	*M. prunifolia* var.....(19651)	*M. spectabilis*.....(849)	Gh. 1916	11	0	.....	.....	.....	...	.....	...	.....
39	*M. ringo*.....(19662)	*M.* Hyslop Crab.....(824)	Gh. 1914	38	9	23.68	81	81	59	72.84	35	59.32
40	*M. ringo*.....(19662)	*M.* Fluke Apple.....(822)	Gh. 1914	23	11	47.83	26	25	13	52.00	3	23.07
41	*M ringo*.....(19662)	*M. spectabilis*.....(849)	Gh. 1911	10	0	.....	.....	.....	...	.....	...	.....
42	*M. ringo*.....(19662)	*M. niedwietzkyana*.....(834)	Gh. 1914	8	6	75.00	33	33	29	87.88	14	48.27
43	*M. toringo*.....(19664)	*M. niedwietzkyana*.....(834)	Gh. 1916	50	2	4.00	2	2	1	50.00	1	100.00
44	*M. toringo*.....(19664)	*M. microcarpa*.....(19644)	Gh. 1916	24	2	8.33	4	4	0	.....	...	.....
45	*M. malus* var.....(19667)	*M. prunifolia* var.....(19651)	Gh. 1914	7	0	.....	.....	.....	...	.....	...	.....
46	*M. malus* var.....(19667)	*M. malus* var.....(830)	Gh. 1916	11	4	36.36	13	13	0	.....	...	.....
47	*M. malus* var.....(19667)	*M. niedwietzkyana*.....(834)	Gh. 1916	12	4	33.33	6	6	1	16.66	1	100.00
48	*M. malus pendula*.....(19688)	*M. ringo*.....(19662)	Gh. 1914	18	0	.....	.....	.....	...	.....	...	.....
49	*M. ringo sublobata*.....(19689)	*M. microcarpa*.....(19644)	Gh. 1914	26	0	.....	.....	.....	...	.....	...	.....
50	*M. ringo sublobata*.....(19689)	*M.* Whitney.....	Gh. 1915	4	0	.....	.....	.....	...	.....	...	.....
51	*M. ringo sublobata*.....(19689)	*M. prunifolia xanthocarpa*....(839)	Gh. 1916	17	0	.....	.....	.....	...	.....	...	.....
52	*M.* Whitney.....	*M.* Yellow Siberian Crab.....	Orch. 1911	93	28	30.00	167	157	90	57.32	59	65.55
53	*M.* Whitney.....	*M. prunifolia* var.....(838)	Orch. 1911	48	25	52.08	161	154	101	65.58	62	61.38
54	*M.* Whitney.....	*M. prunifolia* var.....(856)	Orch. 1912	48	26	54.17	163	151	57	35.19	27	47.36
55	*M.* Whitney.....	*M. baccata maxima*.....(810)	Gh. 1915	5	0	.....	.....	.....	...	.....	...	.....
56	*M.* Yellow Siberian Crab.....	*M.* Whitney.....	Orch. 1911	48	8	16.67	55	48	36	75.00	26	72.22
	Totals.....	.....	.....	1 068	300	28.09	1 600	1 549	753	.....	439	.....

them economically valuable and worthy of being perpetuated. The crab-like forms of Malus have been under the disturbing influences of cultivation for a much shorter period than have the orchard varieties developed from *M. malus;* they are not remotely removed from wild types, their characters have not been greatly modified from those of the primitive forms, they reproduce thru seeds with great constancy. Orchard varieties, on the contrary, can be maintained only by vegetative propagation; multiplied thru seeds they do not come true; there is prompt retrogression to forms nearer the originals in characters and therefore of little or no value. Characters of the crab-like forms may be assumed to possess greater stability, to be more fixed, and more likely to be transmitted as unmodified units. That some characters are more potent than others and more likely to dominate in the progeny is probably true, and behavior of hybrids between plants that are believed to possess such characters will be watched with interest.

Thus far 56 combinations of parents have been attempted in this group; the flowers pollinated numbered 1,068 and the fruits matured 305, a ratio of 1 fruit for each 3.56 pollinations (Table 21). Seven of the combinations—including 302, or 27.6 percent—of all flowers pollinated, and yielding 124, or 40.65 percent of the fruits, were on trees in orchard. Forty-nine of the combinations—with 766, or 71.72 percent, of all flowers pollinated, and 176, or 58.66 percent, of fruits matured—were on potted trees in the greenhouse. The numbers of flowers pollinated in the different combinations are, in general, small; the largest number was 93 flowers of Whitney pollinated in 1911 by Yellow Siberian Crab and producing 28 fruits; the smallest number was four on *M. ringo sublobata* pollinated by Whitney in the greenhouse in 1915 and failing in fruit production; the average for all combinations is about 18.5 flowers. Of the 56 combinations 19 failed to develop fruits; these were all in the greenhouse and included 229 pollinations, or 21.44 percent of the total. Five of the Malus forms used as pistillate parents failed entirely in fruit production; these were *M. baccata maxima* (810) with 5 flowers pollinated by *M. baccata* (806); the Fluke Apple (822) with 11 flowers pollinated by *M. niedwietzkyana* (834); *M. malus pendula* (19688) with 18 flowers pollinated by *M. ringo* (19662); *M. soulardi* with 15 flowers pollinated by *M. niedwietzkyana,* and 5 flowers pollinated by *M. malus* var. (19667), and three combinations with *M. ringo sublobata* as follows: 26 flowers pollinated by *M. microcarpa* (19644), 4 by Whitney, and 17 by *M. prunifolia xanthocarpa.* This leaves the 37 fruit-producing combinations distributed among 20 of the forms of Malus used as mother plants. The success percentage for the group as a whole was 28.09; this was somewhat higher than for the other groups, in which the percentages of success are recorded as follows: Group 1, 12.90; Group 2,

15.83; and Group 3, 22.63. For individual combinations the range for the 37 that produced fruits was from 3.22 percent for a greenhouse combination, in which 50 flowers of *M. toringo* pollinated by *M. niedwietzkyana* yielded two fruits, to 75 percent for a combination in which 8 flowers of *M. ringo* pollinated by *M. niedwietzkyana* produced six fruits. In four combinations less than 10 percent of the flowers pollinated developed fruits, and 13 combinations in each of which more than 50 percent of the flowers pollinated developed fruits.

Because of the small number of matings in this group the tabulation of parental combinations may take a different form from that adopted in presenting the larger groups, and instead of combining all matings for each pistillate parent they may be individually entered, thus giving in detail the behavior of each pair with results brought down to the last enumeration of seedlings.

The number of Malus forms appearing in the 56 matings tabulated is 29, and of this number 17 appear as both pistillate and pollen parents, 8 appear only as pistillate parents, and 4 only as pollen parents. This list of matings is not, as a whole, what would be chosen if it were possible to arrange in advance a schedule of desired pollinations. Most of the pollinations were made in the greenhouse on small trees bearing few flowers; these trees did not all bring flowers to receptive condition at the same time, but spread the flowering period over several weeks. For this reason many of the combinations attempted were those of convenience rather than choice. Effort was made to utilize receptive flowers at the proper time and it was necessary to use such pollen as was available at the time. There was no inclination to deprecate this procedure, because no other course seemed possible, and when it is considered that nothing definite is known regarding the heritable qualities of the tangible characters of these plants, it is evident that the basis on which selection of parents may rest is insecure and not dependable. When progeny of these matings are grown to flowering age and pollinations are to be made as an initial step toward a second generation, the case will be quite different. Immediate parents of the plants will be known, characters will have been studied, compared with those of the parents, and definite impressions formed as to what matings would be desirable. When that time comes plants that are to be mated must be brought to flower simultaneously; this can be accomplished thru the study of vegetative and flowering records, which will enable right decision regarding time of starting growth and temperatures necessary for the proper rate of development.

Seed Production and Distribution in Group 4

The number of seeds saved from the 300 fruits was 1,600, an average of 5.33 to each fruit. This average is higher than for hybrid

fruits of Group 3, in which the average was 4.77 seeds to each fruit, but considerably lower than the average of 7.14 seeds to each fruit in Group 2, or the average of 7.06 seeds for each fruit in Group 1. Individual varieties or species have averages ranging from 1.5 seeds to each fruit for 4 fruits of *M. prunifolia xanthocarpa* and 4 fruits of the dwarf form of *M. toringo,* to 8 seeds to each fruit for 14 fruits of *M. malus* var. (830). The maximum was 12 seeds for one fruit of *M. spectabilis* var. (849). Four parthenocarpic fruits are recorded, three for *M. dioica* and one for *M. malus* var. (19667). The range of seeds for all fruits was thus 0 to 12. There were 30 fruits with 7 seeds each. This was the highest frequency. The normal of 10 seeds to each apple was reached by 12 fruits and but 3 fruits had seeds above this number, 2 fruits with 11 seeds each and the one already mentioned having the maximum of 12.

The purpose of Table 22 is to show seed distribution in the fruits produced from the matings within the group; therefore, only those combinations producing fruits are included. The 19 crab-like forms of Malus listed in the table have representation in 48 combinations, but 11 of these combinations, distributed among nine of the mother plants included in the list, failed in fruit production and, therefore, are excluded, leaving a total of 37 fruit-producing combinations distributed among the 19 different forms of Malus. In this tabulation the totals of fruits and seeds are less than those given in the preceding table; this is because 37 of the fruits produced by *M. prunifolia* (838) had no record of seed distribution and hence, having no proper place in this table, are omitted; these 37 fruits produced 160 seeds, 150 of which were planted, but only 9 germinated.

Losses of Seeds Between Extraction and Planting

The seeds planted were less by 51 than the number saved; a loss of 3.13 percent, a percentage somewhat higher than that for Group 3, but lower than for Group 2, and less than half the loss in Group 1.

Percentages of Germination Vary Widely

Of the 37 combinations producing seeds, six with an aggregate of 63 seeds failed entirely in germination; six other combinations with an aggregate of 44 seeds record only one germination each; one other combination germinated two seeds and one three seeds; above these the numbers for different combinations ranged from 5 to 101. Percentages ranged from 2.75 for 3 seeds germinated out of 109 planted from the 23 fruits of *M. prunifolia* var. (838) X Yellow Siberian Crab, to 93.33 percent for 14 germinated out of 15 seeds planted from the 2 fruits of *M. malus* var. (830) X *M. prunifolia* var. (19651). For all combinations the seeds germinated numbered 753, or 48.61

TABLE 22.—DISTRIBUTION OF SEEDS IN HYBRID FRUITS OF GROUP 4, CRAB-LIKE FORMS OF MALUS X CRAB-LIKE FORMS OF MALUS

Species or variety	Number of parental combinations	Number of fruits	Number of seeds	Average number of seeds to fruit	Seeds to each fruit												
					0	1	2	3	4	5	6	7	8	9	10	11	12
1 *M. baccata*.....(806)....	1	6	25	4.16	...	1	...	...	3	..	2.	...	...	...	...	...	...
2 *M. baccata oblonga*.....(811)....	2	8	15	1.87	...	3	3	2	...	...	...	...	...	...	...	...	...
3 *M. dioica*.....(819)....	2	6	19	3.16	3	...	...	...	1	1	...	...	...	...	1	...	...
4 *M.* Hyslop Crab.....(824)....	1	1	6	6.00	...	...	...	...	...	...	1	...	...	...	...	...	...
5 *M. malus* var .....(830)....	2	14	112	8.00	...	...	...	...	...	...	3	3	2	3	3	...	...
6 *M. prunifolia macrocarpa*.....(837)....	2	18	131	7.38	...	...	...	...	...	4	...	4	7	3	...	...	...
7 *M. prunifolia* var.....(838)....	4	4	20	5.00	...	...	1	...	1	...	...	2	...	...	...	...	...
8 *M. prunifolia xanthocarpa*.....(839)....	1	4	6	1.50	...	2	2	...	...	...	...	...	...	...	...	...	...
9 *M. spectabilis*.....(849)....	1	2	21	10.50	...	...	...	...	...	...	...	...	...	1	...	...	1
10 *M. toringo*.....(853)....	1	10	32	3.20	...	1	3	3	1	1	...	1	...	...	...	...	...
11 *M.* Yellow Siberian C..(857)....	1	2	5	2.50	...	1	...	...	1	...	...	...	...	...	...	...	.
12 *M. siberica frutico coccinea*.....(19643)....	3	33	221	6.70	...	...	...	4	2	4	5	3	8	4	3	...	...
13 *M. microcarpa*.....(19644)....	2	11	66	6.00	...	...	1	1	1	1	2	2	1	2	...	...	...
14 *M. scheideckeri* .....(19646)....	1	4	7	1.75	...	3	...	...	1	...	...	...	...	...	...	...	...
15 *M. prunifolia* var....(19651)....	2	15	43	2.86	...	1	5	6	1	2	...	...	...	...	...	...	...
16 *M. ringo*.....(19662)....	3	26	140	5.38	...	1	7	1	3	3	2	2	1	1	3	2	...
17 *M. toringo,* dwarf...(19664)....	2	4	6	1.50	...	2	2	...	...	...	...	...	...	...	...	...	...
18 *M. malus* var .....(19667)....	2	8	19	2.37	1	1	2	3	...	1	...	...	...	...	...	...	...
19 *M.* Whitney.....	3	79	491	6.21	...	...	3	2	4	14	20	21	11	2	2	...	...
20 *M.* Yellow Siberian Crab.....	1	8	55	6.87	...	...	...	...	1	...	3	1	1	2	...	...	...
Total.....	37	263	1 440	5.47	4	16	20	22	20	31	38	39	31	18	12	2	1

percent of those planted; 30.02 percent germinated in Group 3, 71.99 percent in Group 2, and 62.22 percent in Group 1.

Hybrid Seedlings Now Living

From the 753 seeds germinated within the group there are now living 439 seedlings, distributed according to age as follows:

From pollinations of 1911 and now in the 6th year = 152
From pollinations of 1912 and now in the 5th year = 27
From pollinations of 1913 and now in the 4th year = 33
From pollinations of 1914 and now in the 3d year = 137
From pollinations of 1915 and now in the 2d year = 2
From pollinations of 1916 and now in the 1st year = 88

Those seedlings from pollinations of the four earlier years are planted in orchard. They number 349, or 79.49 percent of the group total. The others are in nursery and, like the earlier ones, will be given permanent positions when two years old. The living seedlings represent 58.30 percent of the seeds germinated, a percentage less than for any of the other groups; the record for Group 1 is 73.67 percent; for Group 2, 73.98 percent; and for Group 3, 66.21 percent.

For the lots of different ages the percentages of germinations persisting as seedlings range from 37.5 percent for the lot of 33 trees now in their fourth year, to 87.12 percent for the 88 seedlings from germinations of last spring. The seedlings now in their sixth year represent 64.40 percent of the germination in 1911 and unless attacked by disease or killed thru accident they should all reach fruiting age. Younger lots are more likely to meet with losses, but examination of the seedlings indicates that for all lots the elimination of constitutionally weak individuals has been already accomplished, so that except for some unusual catastrophe, such as might occur from winter cold or summer storm, it is expected that further losses will be small.

THE GENUS MALUS

The genus Malus instituted by Tournefort[1] in 1700 included five species; one of these, *sylvestris*, has two varieties; under another, *sativa*, the cultivated apple, are recorded twenty-nine varieties. The names and descriptive phrases used are credited to earlier writers, among whom are Ruellio, 1536, and C. Bauhin, 1623 and 1671. Several are credited to the "Hortus Regius Parisiensis," a work published in 1665. Malus, the apple genus, was separated from Pirus, the pear genus, on form characters. Linnaeus in 1735 used the Latin term Pirus generically to designate the apple family, including all pomaceous fruits, and Malus became the specific name of cultivated apples and their supposed originals.

Notwithstanding various efforts to separate them, apples and pears remained in the genus Pyrus until 1897, when Britton and Brown[2] reestablished the genus Malus, basing the separation upon the single character, the presence in pears and the absence in apples of grit-cells in the flesh. Earlier attempts to segregate, based upon distinct styles in pears and more or less connate styles in apples, failed because of the inconstancy of the character; in like manner red anthers are not characteristic of all pears any more than yellow anthers are characteristic of all apples; so too, all apples are not umbilicate at both base and apex, nor are all pears umbilicate at apex only. For the great majority of both pears and apples there are characters which readily distinguish the one from the other, but these characters are not universal thruout the respective genera. The separation of apples and pears by Britton and Brown, on the presence or absence of grit-cells is generally accepted, but Carriere[3] has pointed out that this character, like others that have been referred to, is not perfectly constant; he cites *Malus sempervirens* (synonym of *Pyrus* [*Malus*] *angustifolia*, according to "Index Kewensis") as an example of an apple whose fruits very often contain these grit-cells. Carriere adds that there is scarcely an organic character that is truly differential between apples and pears unless it be the presence in apples of an acid which is said not to exist in pears, but the constancy of this character this writer does not care to affirm.

The apples constitute a natural group as worthy of distinction as are many other botanical groups which in rare instances fail in those characters which separate them from closely allied groups. The apple genus contains very diverse forms; there are low straggling shrubs and tall fastigiate trees, flowers that range in spread from 10 mm. to 60 mm., and fruits from the size of small peas to those above 4 inches in

[1]Tournefort, J. P. Inst. Rei Herb. 1700.
[2]Britton and Brown. Illus. Fl. 1897.
[3]Carriere, E. A. Rev. Hort., 295. 1881.

diameter, but they are all apples and, with few exceptions, are readily recognized as such. That there is great confusion in the nomenclature of the species of the genus is a fact of which any one who undertakes classification of the forms will soon become convinced. Britton and Brown accord fifteen species to the genus, but the names that have been used to designate apple forms, regarded as good species by the authors, reach a number far in excess of this.

The "Index Kewensis," issued in 1895 and supposed to contain all plant names used up to 1885, lists 318 specific names under the genus Pyrus. The authors recognize 95 of these names as valid and 223 are considered as synonyms. About 70 of the specific names belong to the Malus section of the genus, possibly a little in excess of this number, for there are a few names that cannot be located, even in section, without consulting original sources that are not available.

Sections of the genus other than Malus, as Pyrus, Sorbus, Mespilus, Aria, and Crataegus, are represented by 210 names. Of the names known to belong to Malus, 18 are retained as valid while the rest are listed as synonyms. Twenty-five of the names applied to forms of Malus are recorded as synonyms of the one species *Pyrus malus,* the common apple. J. C. Loudon[1] under the genus Pyrus lists 20 species, 11 of which are pears and 9 apples. Martyn's Miller's Dictionary of 1807 lists 13 species of Pyrus; 3 are pears, 8 are apples, and 2 are quinces.

The number of names used as specific designations of forms of apple is sufficient to show wide variations, and the large proportion of names that have been relegated to lists of synonyms indicates differences in judgment on the part of those botanists who have worked with the group. Doubtless a considerable number of the specific designations were based upon differences too slight or too ephemeral to stand the test of time and examination of more abundant material; others that are still recognized as species may and very likely will be discarded by the monographer who attempts a complete revision of the genus. The 51 forms received for breeding purposes include 31 with specific names: 3, namely, Hyslop Crab, Yellow Siberian Crab, and Fluke Apple, that appear under their common names only; 2 are unnamed forms; while the remaining 15 are varieties of *M. baccata, M. prunifolia, M. toringo,* and *M. malus.* Included among the varieties are 7 hybrids as follows: *M. baccata* X *M. prunifolia, M. baccata* X *M. toringo, M. malus* X *M. baccata,* all of the 800 series, and *M. baccata* X *M. malus* (3549), *M. baccata* X *M. floribunda, M. malus* X *M. baccata,* and *M. baccata* X *M. toringo* of the 19000 series. These hybrids all proved to be weak; while some of the scions started growth after grafting, all finally died and passed out of the collection.

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[1]Loudon, J. C. Arboretum et Fruticetum Britannicum 2. 1838.

All of the species and varieties included in the Malus collection have produced flowers and fruit, and a large proportion of them have been used in breeding. To record as accurately as possible the characters possessed by each form that has entered into any of the parental combinations, detailed descriptions are necessary, and these now follow alphabetically as nearly as can be and still bring together those forms appearing under the same specific name.

DESCRIPTION OF MALUS FORMS USED IN BREEDING

1. *Malus angustifolia* Michx. (19676,801,1204)

First recorded by Aiton[1] as *Pyrus angustifolia.* Placed in the genus Malus by Michaux in 1803.

Nuttall (1818), Torrey (1826), Eaton (1833), Gray (1860), Chapman (1883), and other botanists retained Aiton's position for the plant under Pyrus. Britton and Brown (1897) restored it to Malus. This has been included in each of our three series. As 19676, one root-graft was made March 23, 1907. The graft grew, but is described as very weak; it was alive July 20, 1907, but died in the early fall.

As 801, ten top-grafts on a Sops of Wine tree were made April 4, 1908. Six of these were alive in the fall of 1908, but the growth was weak and the various grafts died during the summer of 1909. Ten root-grafts were made January 17, 1908; these started growth, but only two were living in the fall; these were stored for the winter and replanted in the spring of 1909, but both died during the summer.

As 1204 the scions were root-grafted on apple seedlings January 10, 1912. On October 23, 1912, six of ten made were living and the average growth for the season was 3.29 inches. Two of the trees lived to be planted in orchard April 14, 1914; one of these died the following year and one survived until sometime during the summer of 1918. Death of these trees was anticipated because of the very feeble growth from the beginning. When scions were received in 1912, some were worked on both paradise and Doucin stocks; these grafts started growth, but died before the end of the season. On April 6, 1914, two scions taken from one of the trees root-grafted in 1912 were grafted on paradise stocks growing in 8-inch pots. One of these is in the greenhouse for the 1924 season. It is very small and of straggling growth. It flowered sparingly in 1918 and in each year since. In 1918, 25 flowers pollinated by Twenty Ounce yielded 2 fruits containing 13 seeds, 8 of which germinated; 3 seedlings lived to be planted in nursery, 2 were living in 1919, one in 1920, and this died in 1921. Also in 1918, 9 flowers pollinated by Fameuse yielded 1 fruit which contained 6 seeds, 5 of which germinated and produced 5 seedlings which were planted in nursery; one of these survives, is 5 years old, 36 inches high, 21 inches in spread, and 0.6 inch in trunk diameter. The

[1]Aiton, William. Hort. Kew. ed. 1, 2, 176. 1789.

size of the tree does not indicate vigor, but it may live to fruiting.

The experience with *M. angustifolia* here detailed shows that it does not succeed on any stocks tried, nor does it do well when top-grafted on apple varieties. The species is now represented by *one small tree on Doucin stock* in a pot in the greenhouse and as the female parent of one seedling from the cross by Fameuse.

A small tree with open-spreading crown and rigid, thorny branches; native in the South and known as the Southern Crab or Narrow-leaved Crab. Leaves lanceolate or narrowly elliptical, 50 to 80 mm. long, 20 to 35 mm. broad, cuneate at base, serrate or crenate-dentate or sometimes nearly entire, apex obtuse, light green, rather thin, but rigid and shining, pubescent when young, becoming glabrous; stipules small, very narrow.

Flowers.—Those for description were from a cluster of 6 from a lateral bud on a terminal twig; buds oblong, rounded at apex, quite variable in size, deep pink. Pedicels 16 mm. long, slender, glabrous; calyx lobes narrowly triangular, acuminate, erect, of medium size, glabrous outside, pubescent inside; petals 5, ovate with rounded apex, claw 4 mm. long, slender, separated, deep pink. Stamens 20, filaments slender, 10 to 13 mm. long, anthers large, plump, orange, tinged red; styles slender, tinged red, connate at base, hairy up to the point of separations, stigmas small, capitate.

Fruit.—Roundish-oblate, rather pale yellowish-green, with rounded regular base and an irregular ribbed apex, of medium size from the crab standpoint. A single fruit weighs 14.2 grams, has a vertical diameter of 25 mm. and a transverse diameter of 31 mm., not umbilicate at base, basin of medium depth, narrow, acuminate, irregular, dots are few, small, round, white, mostly about the apex, inconspicuous. Calyx tube is large, cylindrical, of medium length, core small, round, median, closed, core lines clasping, cells axile, uniform, carpels obovate, entire, tufted, concave; seeds of medium size, plump, dark; flesh greenish, firm, crisp, juicy, very acid; stem slender, 37 mm. long, erect, green, glabrous; calyx small, glabrous, closed; appears like fruit of *M. coronaria* and *M. ioensis* and has the same fragrance.

M. angustifolia is closely related to *M. coronaria* and by some has been thought to be only a variety of that species. Thomas Nuttall[1] says of this variety:

"... This appears to be scarcely more than a variety of the *Pyrus coronaria;* distinguishable indeed, by its narrower leaves, usually entire, which are often acute below; but as the styles are neither perfectly distinct nor constantly glabrous, and that the young leaves are also pubescent, no sufficient distinction remains. The fruit is likewise wholly similar."

The species is, however, generally accepted as valid and as having a southern range from Pennsylvania to Florida, and west to Kansas and

[1]Nuttall, Thomas. N. Amer. Silva 1, 174. 1857.

Louisiana. *M. coronaria* is more northern, ranging from western New York to Wisconsin, and south. Doubtless the ranges of the two species overlap in many places and it requires no stretch of the imagination to assume that there are intermediate forms so nearly like the respective species as to be almost, if not quite, indistinguishable. If the tree now in the greenhouse continues to live other crosses will be attempted, but from the experience up to this time, the species will probably never be regarded as valuable as a parent in breeding at this Station.

2. *Malus arnoldiana* (802)

This species was described in the plant list received from the Arnold Arboretum as "a seedling of *M. floribunda* that originated in the Arnold Arboretum and shows the influence of the blood of *M. prunifolia* by its larger flowers."

FIG. 7.—TREE OF *M. arnoldiana* ON MAY 9

Flowers are produced in great profusion, both from terminal buds of shoots and spurs and from lateral buds of shoots of the previous year.

Scions received in January, 1908, were root-grafted on apple seedling stocks January 17, grown two years in nursery, and on April 30, 1910, were planted in orchard. In following years scions from these first trees grafted were worked, both as root-grafts on common stocks and as top-grafts on orchard varieties and on paradise stocks. Trees grew vigorously and several of them have been flowering and fruiting

each year since 1912. One of the trees grafted in January, 1908, and now 16 years old, is 14½ feet high, has a spread of 19 feet, 2 inches, and a trunk diameter of 6.1 inches.

Until trees are seven or eight years old they are very symmetrical, with rounded somewhat spreading crowns; after this age the rounded outline becomes somewhat broken by protrusion of long willowy shoots, a characteristic which is very pronounced in *M. floribunda* and all descendants from that species. The general direction of the numerous branches is ascending and somewhat straggling. Internodes are, in general, short to medium, ½ to ¾ inch long.

Flowers are produced in great profusion, both from terminal buds of shoots and spurs and from lateral buds of shoots of the preceding year. At flowering time each tree is a dense mass of bloom and very ornamental (Fig. 7). Bark of trunk light grayish-brown, smooth, lenticels few, small, round or oval; twigs reddish-brown, the younger with yellowish-green tinge, glabrous. Buds rather small, short, thick, pointed, reddish-brown, glabrous.

Leaves.—When trees are in flower the young leaves are ½ inch to 2 inches long, various in form, mostly elliptical, oblong or oval, tapering at base, acute or acuminate or some of the smaller obtusely rounded at apex; most young leaves have margins quite regularly serrate, but some are crenate-serrate; when young, leaves are scantily pubescent both above and below, becoming glabrous above and retaining a few hairs along the midrib below; dark green above, lighter below, petiole pubescent, channelled.

For an accurate determination of range in size 100 leaves, half from terminal shoots and half from lower branches, were taken by random selection and measured on June 26; dimensions were as follows:

		Top terminal shoots	*Lower branches*
Length	maximum	119 mm.	125 mm.
	minimum	74 mm.	42 mm.
	average	97 mm.	86 mm.
Width	maximum	46 mm.	34 mm.
	minimum	21 mm.	14 mm.
	average	34 mm.	25 mm.
Petiole length	maximum	33 mm.	40 mm.
	minimum	17 mm.	13 mm.
	average	23 mm.	28 mm.

		Top terminal shoots	*Lower branches*
Apex	acute	37	47
	acuminate	2	0
	obtuse	11	3
Margin	serrate	34	12
	crenate	0	4
	crenate-serrate	16	34

Leaves from top terminal shoots are somewhat longer than those below, but the lower leaves average a little wider and have longer petioles. Stipules are ½ to ¾ inch long, lanceolate, petiolate, often with one or two pairs of teeth or small lobes near the base, inclined to persist.

Flowers.—Each mixed bud produces from 5 to 7 small leaves and from 4 to 8 flower buds; these are terminal and lateral on spurs and on shoots that are from 6 to 24 inches long; internodes on flowering shoots are mostly short, bringing the flowers so close together that when open they are in contact, completely obscuring twigs and leaves; this is, in part, due to elongation of the bud axis which may amount to as much as ¾ inch with perceptible separation of the leaf and flower bearing nodes. Buds are, at first, small, globular, and dark pink in color; as they approach anthesis they become larger, pointed, and much lighter in color. Flowers expand 35 to 37 mm. and are mostly pure white; occasionally a faint pink tinge is retained. Pedicels slender, green, glabrous, bracteate, averaging 35 mm. in length. Ovary glabrous, dull red. Calyx lobes lanceolate acuminate, dull red, glabrous outside, pubescent within, deciduous, falling soon after flowering. Of 4,000 fruits examined not one retained the calyx lobes. Petals oblong-ovate, rounded at apex, abruptly contracted at base to the very short claw. 17 to 20 mm. long by 8 to 10 mm. in width; anthers plump, oblong, light yellow. Pollen usually abundant and, after dehiscence of the anthers, tending to become powdery; not cohering in masses; styles 3 or 4, slender 8 to 10 mm. long, connate one-third the length, hairy in a narrow belt about the point of separation; stigmas oval, oblique.

FIG. 8.—SHOOT OF *M. Arnoldiana* IN FULL FLOWER, APRIL 29

Fruit.—Small, round, slightly conical, tapering towards the truncate apex to the margin of the russet scar left by the deciduous calyx lobes; the average of 100 fruits, weight 1.54 grams, is 12 mm. in vertical diameter by 13 mm. in transverse diameter; yellowish-white, often with a bronze or pinkish blush where exposed to the sun; no bloom; skin thin, tough, polished, dots none; cavity shallow, narrow, acute, reg-

ular; basin a plane or sometimes very slightly depressed surface outlined as a russet scar with a minute central depression that represents all there is of a calyx tube. Stem slender, varying from 25 to 40 mm. in length, glabrous, yellow streaked with red. Core large in pro-

FIG. 9.—FRUITING BRANCH OF *M. arnoldiana*, SEPTEMBER 16

The mature fruits are a pale yellow. A considerable proportion of the fruit hangs on the trees until the buds push it off in the spring.

portion to the size of fruit, round, closed, core lines terminating within the limits of the circular apical scar; cells axile, round, uniform; carpels obovate, glabrous, deeply concave. Seeds plump, of medium size, light brown; flesh yellowish, firm, juicy, acid, astringent, inedible. A

considerable portion of the fruit persists thru the winter, falling as the buds push in spring; these hold-over fruits are brown and shrivelled and do not enhance the winter aspect of the trees.

This form has value as an ornamental when in bud and especially when in full flower; the bloom is so massed as to be conspicuous and very handsome. A twig in full flower is shown in Fig. 8. Again in autumn when the pale yellow of mature fruits is attained, the tree is attractive, but not so conspicuous as are some of the crimson-fruited forms. The fruiting stage is illustrated in Fig. 9 and a single fruit is shown at the extreme left in Fig. 44, page 498.

M. arnoldiana closely resembles *M. floribunda*, but the tree is more symmetrical, the bark much lighter in color, the flowers much larger, and the fruit slightly larger. Buds of *M. floribunda* are more deeply colored and the open flowers retain more pink than do the flowers of *M. arnoldiana*. Calyx lobes are deciduous in both, and both retain fruits thru the winter.

3. *Malus astracanica* (19670,803)

Malus astracanica Dum. Cours., ed. 2, 5, 426. 1811.
Pyrus astracanica De Candolle Prodr. 2, 635. 1825.

Given as a synonym of *Pyrus malus* in "Index Kewensis." This form of Malus is represented in the collection in both the 19000 series and in the 800 series. It has propagated readily both as root-grafts and as top-grafts. Top-grafts began flowering at four years from the graft, but first flowers from root-grafted trees did not appear until the ninth year. Bloom has been scanty on all trees in all years, with the one exception that a top-grafted tree at ten years of age in 1922 is recorded as having full bloom. Trees are very vigorous, upright in habit, with dense foliage. Bark of trunk light brown with a greenish tinge, of two-year-old wood, greenish-brown, and of twigs reddish-brown; new shoots pubescent; internodes ¾ to 1¼ inches long; lenticels numerous, small, round.

Leaves.—Large, broadly ovate or oblong, 3 to 5 inches long, 1½ to 3 inches broad, acute, crenate-dentate, white tomentose on both sides when young, becoming glabrous above; petioles 1 to 1½ inches long, stout, pubescent, channelled; stipules ¼ to ½ inch long, linear, soon falling from most leaves. Leaves from mixed buds are ovate, 1 to 2 inches long, acute or obtuse, covered both sides with soft white tomentum.

Flower buds globular, dark pink, fading as they approach anthesis. Pedicels short, 13 to 14 mm. long, stout, densely white tomentose, bracteate; ovary gray, pubescent.

Flowers.—Calyx lobes 5, triangular, acuminate, 7 mm. long, 2½ mm. wide at base, pubescent both sides, becoming reflexed even before flowers are fully open. Flowers expand 32 mm. Petals oval, 16 mm.

long, 12 mm. broad, white inside, but more or less spotted with pink on outer surface, claw broad, 1 mm. long; stamens 20, filaments slender, 5 to 8 mm. long; anthers plump; light, creamy yellow; styles short, 8 mm. long, stout, connate for 5 mm. from base, hairy from base to point above separation, tips flattened, irregularly oval.

Fruit.—The fruit described was the first fruit matured by a root-grafted tree in its ninth year and was picked July 28, 1916; it weighed 112.2 grams, measured 54 mm. in vertical and 70 mm. in transverse diameter; oblate in form, base regular, rounded, apex regular, transverse section obscurely ribbed, sides equal; ground color yellow, blushed with light red and streaked with a darker red, bloom scanty,

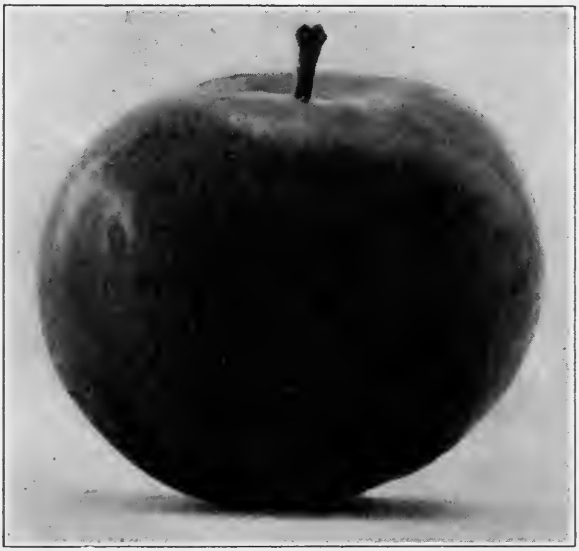

FIG. 10.—FRUIT OF *M. astracanica*, JULY 28, NATURAL SIZE

waxy white, skin smooth, thin, tough; dots many, small, round, russet, most numerous about apex, inconspicuous; cavity shallow, medium in width, obtuse, regular; basin shallow, medium in width, obtuse, slightly wrinkled; stem 14 mm. long, slender, clavate, erect, russet, pubescent; calyx rather small, pubescent, closed. Core of medium size, cordate, median, half-open; stamens marginal, core lines clasping; cells axile, uniform; carpels roundish, entire, glabrous, concave; seeds plump, of medium size, dark brown. The 5 cells contained 9 plump seeds and 1 undeveloped ovule. Flesh yellowish, tender, juicy, aromatic, flavor subacid, good.

From observation of *M. astracanica* as grown here, it does not appear to be specifically distinct, but should have place as a variety of *M. malus* in the Red Astrachan group.

4. *Malus atrosanguinea* (804)

This species was also received as No. 19636 from the U. S. Department of Agriculture. The list accompanying the scions carried the following note: "*Malus atrosanguinea* is probably a hybrid between *Malus toringo* and *Malus floribunda*." No authority for the species is given and in available publications the name is not to be found except that a writer in "The Garden" does use *atrosanguinea*, in a brief note, as a varietal name. The note in Vol. 27 (1885) p. 247, is as follows:

"*Pyrus floribunda atrosanguinea*, this is a hybrid between the Japanese *Pyrus floribunda* and the Chinese *Pyrus spectabilis*, both very free-flowering and very handsome Crabs. It has the habit, the floriferousness and the deep color of the former plant and the large flowers of the latter. It is said to be an excellent subject for forcing; in any case it is a very handsome, hardy-flowering shrub. It originated a few years ago in one of the Dutch nurseries and no doubt ere long when better known will be widely cultivated in this country. N."

The varietal form referred to here may be, and probably is, distinct from the form received here as a species. The two may have come from entirely different sources and be widely different in their chief characteristics, but in the absence of detailed descriptions upon which the form names were founded it is impossible to decide upon the validity of the names as used.

Propagation of the scions received in the 19000 series was successful, but the scions had been so reduced in vitality by drying that growth was weak and the plants did not live beyond the first season.

The scions received in 1908 were grafted both as root-grafts and as top-grafts. The top-grafts lived and made a feeble growth thru three seasons and then died. Root-grafts grew vigorously and were planted in orchard in the spring of 1910. One of these trees remains; the others were removed two years ago in thinning the plantation; this tree as measured in the fall of 1923 is 13 feet, 10 inches high, spreads 21 feet, 9 inches, and has a trunk diameter of 7.6 inches. It is now sixteen years from graft and has been bearing since 1912. Other trees were propagated in 1912 and in 1914 and the form is well represented in the collection.

Tree.—Rather low and very wide spreading, producing numerous rampant shoots which give a straggling appearance. The crown is very open; shoots are mainly ascending, but some are horizontal and occasionally drooping. Internodes are of medium length, ¾ to 1 inch long. Bark of trunk a light grayish-brown; twigs reddish-brown. Lenticels numerous, small, oval, conspicuous on young wood. Buds small, broad, obtuse.

Leaves.—Very variable in size, 1 to 4 inches long, the smaller lanceolate or oblong, or very small ones orbicular; the larger ovate-lanceolate, often 3-lobed; mostly crenate, some distinctly serrate, acu-

minate, or sometimes acute; glabrous and shining above, scantily pubescent below, very dark green above, light green below. Petioles vary from stout to slender, ¾ to 1 inch long, pubescent, channelled; stipules persistent, lanceolate; texture leathery. All buds on wood of the preceding year do not start, 4 or 5 contiguous buds produce leaves, while the adjoining 4 or 5 buds remain dormant. This gives a discontinuous appearance to the foliage.

Flowers.—Flowers are borne from terminal and lateral buds of shoots and spurs, the great majority coming from lateral buds on long shoots, 1 to 3 feet long; sometimes the flowering is continuous, but on many shoots there are groups of buds that produce leaves only, and still other groups that remain dormant so that the flower masses are discontinuous; this detracts from the continuity of color, and trees in full flower are not so attractive as are trees of *M. floribunda* and *M. arnoldiana*. A branch on which flowering is nearly continuous is shown in Fig. 11. Flower buds are, at first, globular, becoming oval just before opening and measuring 8 mm. in length by 5 mm. in breadth, very deep red. A twig of this species, as it appeared in bud, April 21, 1915, is shown in Fig. 12.

FIG. 11.—BRANCH OF *M. atrosanguinea* IN FLOWER, APRIL 29. FIG. 12.—TWIG IN BUD, APRIL 21

The individual flower expands from 15 to 20 mm.; calyx lobes oblong, acute, dull purplish-red, glabrous outside, pubescent within, this pubescence especially dense along the margins. Erect in bud, becoming horizontal in open flowers. Petals oblong or elliptical, 9 mm. long by 6 mm. broad, rounded at base to the very short claw; in bud they are intensely dark red, but fade somewhat when expanded; however, in no other form of Malus represented in the collection except *M. niedwietzkyana*, do the petals retain as much color as in this—even when ready to fall they are of a distinct reddish-pink color. Stamens 20, filaments slender, 5 to 7 mm. long, anthers light yellow, plump; styles

5, slender, 8 mm. long, connate one-third the length, hairy at base, upper half tinged red; stigmas oval. Pedicels 22 mm. long, green, more or less blotched and streaked with dull red, slender, pubescent; ovary pubescent, dull red.

Fruit.—Small, nearly round, the longitudinal diameter usually slightly longer than the transverse diameter. The average of 100 fruits weighs 0.64 gram, has a vertical diameter of 10 mm., and a transverse diameter also 10 mm.; color greenish-yellow with a reddish-pink blush on one side; bloom scant, waxy white; skin smooth, thin, tough; cavity none; basin a small russet scar scarcely depressed; no calyx tube. Calyx lobes deciduous, but not so completely as in either *M. arnoldiana* or *M. floribunda;* of 2,037 fruits examined, 1,900 or 93.2 percent had lost the lobes, 120 still retained the lobes, but separation had taken place and they were apparently ready to fall; in 16 fruits the lobes were half persistent, that is to say, two or three of the lobes had become separated, had fallen, or were ready to fall, while those remaining were still fleshy at base and plainly persistent. In one fruit all the lobes had fleshy bases and were truly persistent. Core large, closed, core lines not apparent; cells axile, obovate; carpels obovate, entire, glabrous, deeply concave; seeds small, light brown; flesh yellowish, firm, dry, acid, and astringent. Fruit of *M. atrosanguinea* is illustrated in Fig. 13, and a single fruit is shown, the second from the right in Fig. 44, page 498.

FIG. 13.—TWIG OF *M. atrosanguinea* IN FRUIT, SEPTEMBER 2

M. atrosanguinea agrees quite closely, in its characters, with *M. floribunda;* but not so closely with *M. toringo,* especially as regards habit of growth and foliage. Still there appears no reason why it may not be accepted as a hybrid between these two species. *M. atrosanguinea* has flowers that average a little smaller than those of *M. floribunda* or *M. toringo;* its fruits average a little larger than those of either of the assumed parents. Leaves of flowering shoots are quite similar in the three forms, but on non-flowering shoots they are different; leaves of non-flowering shoots of *M. floribunda* are not lobed and are, in general, shorter and broader than are leaves on similar shoots of *M. atrosanguinea* and *M. toringo.*

Malus baccata L. Mant. 75 (1771)

The Siberian Crab, a crab with berry-like fruits, is represented by numerous forms, many of which have been given varietal names. The forms of the species have hybridized freely with wild forms of the common apple and with forms of other species until it is doubtful if the original form can ever be definitely known. The species as at present understood ranges over Siberia, Japan, and China, and in those countries has been cultivated as an ornamental for a long period. Varieties are established chiefly upon fruit characters and they exhibit wide differences in form, size, and color. Dr. Eduard Regel,[1] for many years Director of the Imperial Botanic Garden at St. Petersburg, Russia, in "Gartenflora," a journal of which he was the editor, records seven of the most beautiful varieties, illustrating the fruits by a handsome colored plate. These fruits vary in transverse diameter from 10 to 23 mm., in color from yellow to bright scarlet. He remarks that there are many other forms that differ widely from each other.

Scions of twelve forms of *M. baccata* were included in the 19000 series received in 1907. These scions were root-grafted and most of them started growth, but none were able to overcome the injury from drying in transit and all died before the end of the first season. Scions of the 800 series received in 1908 included eleven forms of *M. baccata* labelled as below:

805 *M. baccata aurantiaca*
806 *M. baccata* red fruit 443-1
807 *M. baccata* bright red fruit, late
808 *M. baccata* var.
809 *M. baccata* var.
810 *M. baccata maxima*
811 *M. baccata oblonga*
812 *M. baccata* X *prunifolia*
813 *M. baccata sanguinea*
814 *M. baccata* var. *sieboldi*
815 *M. baccata* X *toringo*

Scions of three of the forms did not grow and these numbers (805, 812, and 815, the two latter hybrids) were eliminated the first season. The scions of a fourth number (809 *M. baccata* var.) put forth shoots which from the beginning were weak, and the last one died early in the fall of 1910. The remaining seven forms are now represented by trees and six of them have been used in breeding; five in 1913 and the three following years, and one in 1915 only. The seventh, 813 *M. baccata sanguinea,* is later than the others in flowering; one of the trees produced 2 flower clusters in 1915 when seven years old, and again in its eighth year a few clusters only. Scions from one of the trees were grafted on dwarf stocks in pots in February, 1911, and have now been in the greenhouse for twelve winters; these trees began flowering in 1914, the fourth year from graft, and have fruited each year since.

These forms of *M. baccata* may be described in the order of the serial numbers beginning with—

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[1]Regel, Eduard. Gartenflora 2, 201-203. 1853.

5. *Malus baccata* (806), red fruit 443-1

Five trees were root-grafted in January, 1908; all grew vigorously. Two years ago four were taken out.

The tree remaining is now, at sixteen years from graft, 19½ feet high, spread 17 feet, and is 6 inches in trunk diameter. The habit of

FIG. 14.—TREE OF *M. baccata*, RED FRUIT (806)

This tree, eight years from graft, shows the erect symmetrical habit of growth which characterizes the variety (Cf. 807, Fig. 15).

growth of this form is erect and symmetrical. Bark of trunk light greenish-brown, of two-year-old twigs gray-green, of new shoots green more or less striped with dull red. Lenticels numerous, small, round; young shoots pubescent, soon becoming glabrous; internodes ½ to 1½

inches long. This variety differs from the next, No. 807, in its more strictly erect habit. (Compare Figs. 14 and 15.)

Leaves.—Elliptical to broadly ovate or some of the smaller oblong-ovate; 2½ to 4 inches long, acuminate, serrate, or crenate-serrate or

FIG. 15.—TREE OF *M. baccata*, RED FRUIT, LATE (807)

The trees of this variety lack the symmetry of variety 806. They have widely spreading branches and an open top. This tree was photographed October 2, eight years from graft.

sometimes, in part, dentate. Leaves from young shoots have stout, pubescent petioles 1 inch long; from buds of spurs petioles are slender, 1¼ to 2 inches long, nearly glabrous. Young leaves are glabrous above and slightly pubescent along the ribs below; dark green and shining

above, light green below. Stipules from linear to lanceolate, ¼ to ½ inch long, caducous; texture somewhat leathery.

Flowers.—Most flowers are borne from terminal and lateral buds on terminal shoots; occasionally from terminal buds of spurs below, but most spurs are non-flowering. On some shoots every node has its

FIG. 16.—FRUITING BRANCH OF *M. baccata,* RED FRUIT (806-2), SEPTEMBER 16

flower cluster and when expanded the flowers are massed together, but on other shoots only a portion of the buds bear flowers and on these leaves are more conspicuous and the color less massed. Buds 5 or 6 in each cluster, pink, but fading as flowers approach anthesis; pedicels slender, 40 mm. long, pubescent. Calyx lobes 5, triangular acuminate, pubescent both sides, erect in bud, becoming reflexed in open flowers, 6 mm. in length. Petals 5, oval, 11 mm. long by 8 mm. wide,

rounded at base to the very short claw, pure white. Flower expands 30 mm. Stamens range in number from 11 to 20 with an average for 27 flowers of 18; filaments slender, 5 to 8 mm. long; anthers plump, light yellow. Styles 5, slender, 12 mm. long, distinct nearly to the base, hairy from base up more than half the length; stigmas small, round.

Fruit.—The ground color of mature fruits is a clear yellow, the over-color is crimson where exposed to sun, varying to lighter red tints in shade. The coloring is handsome, suggesting certain of the sweet cherries in the shading of yellow and red. The form is oblate, vertical diameter, as averaged from 600 fruits, 20 mm., transverse diameter 25 mm., sides equal, bloom scanty, powdery; skin smooth, thin, tough; dots few, inconspicuous, small to medium, round, white or sometimes russet; cavity shallow to medium in depth, rather narrow, acute, often somewhat irregular; stem long, 26 to 36 mm., slender, clavate, green, often streaked with red, pubescent; basin shallow, usually rather broad, obtuse, generally more or less ribbed; calyx tube small, short, conical. Calyx lobes not so completely deciduous as are those of *M. arnoldiana* or *M. floribunda*. Of 7,676 fruits examined, 924, or 12 percent, had either partially or wholly persistent lobes; 88 percent had deciduous lobes, but the deciduous lobes do not fall so early as in some other kinds; some altho completely separated remain until maturity of the fruit. Core is of medium size, oblate, median, closed; cells axile, variable in size; seeds of medium size and of a medium brown color; flesh yellowish, firm, juicy, subacid, astringent.

A fruiting branch as it appeared September 16 is shown in Fig. 16. This variety of *M. baccata* is attractive when in flower altho the flowers are mostly confined to the extreme top of the tree and do not present such masses of color as are characteristic of *M. floribunda* and its nearly related forms. It is especially attractive in autumn, because of the brilliant red of the mature fruit, and there is also something pleasing in the erectness of growth.

6. *Malus baccata* (807), bright red fruit, late

As with the preceding variety (806), this is represented in the collection only in the 800 series; there are several trees from grafts made in different years. The oldest from grafts made in January, 1908, is sixteen years old and one of the trees measures 19 feet 2 inches high, with a spread of 17 feet, and trunk diameter of 7.6 inches.

Tree.—Spreading in habit, producing long slender branches which are much less erect than are similar branches of 806. Altho these two varieties of *M. baccata* are represented by trees having practically the same height and spread, the two trees are very different in appearance; the first (806) is quite strictly erect with thick top; the second (807) has branches widely spreading, open top, and absence of that

symmetry that characterizes 806. All trees grown of this variety are vigorous and healthy. Internodes short, ¼ to ¾ inch in length, buds small, narrow, acute; bark of trunk greenish-brown, twigs dark brown; young twigs scantily pubescent; lenticels irregular in distribution, not numerous, small, in part round, in part elongated. A tree at eight years from graft is shown in Fig. 15.

Leaves.—Mostly elliptical, varying to ovate or obovate, or some of the smaller orbicular, 1 inch to 5½ inches long by ¾ to 1½ inches wide; acute or acuminate, sharply serrate, glabrous and shining dark

FIG. 17.—TOP-WORKED TREE OF *M. baccata* (807) IN FLOWER, MAY 9
FIG. 18.—FLOWERING BRANCH OF SAME, APRIL 29

green above, scantily pubescent and light green below; petioles slender, 1¼ to 1¾ inches long, pubescent. Laminae taper more or less abruptly at base; texture thin, stipules falling early.

Flowers.—Produced from terminal and lateral buds on terminal shoots as well as from terminal buds of spurs thruout the tree. A top-worked tree, four years from graft, in flower May 9, 1916, is shown in Fig. 17. Often the bud-axis elongates from ¼ to ½ inch distinctly separating the leaves and in some cases the pedicels as well, hence,

while some bud clusters appear umbellate, others approach the raceme in appearance; buds vary from 4 to 8 in each cluster. Flower buds globular and dark cherry-red, retaining the color until near the time of opening; they become oval in form with rounded apex, and fade, as they open, to a bright pink which becomes less and less pronounced until the petals are nearly white. Flowers do not become pure white as in 806, but retain a more or less pink tinge to the last. Expanded flowers measure 30 mm. across. Pedicels long, slender, 45 to 55 mm., pubescent, green; ovary green, densely tomentose. Calyx lobes 5, oblong, acuminate, pubescent both sides, 6 mm. long, erect in bud, becoming reflexed in open flowers, green or often spotted, or streaked with red about the base. Petals 5, rounded at apex, abruptly rounded at base to the short, but distinct claw; 15 mm. long by 9 mm. broad, bright pink as they open, but soon becoming white with irregular areas tinged or streaked with light pink. Stamens 18 to 20; of 7 flowers from 1 cluster, 5 had 20 stamens each and 2 had 18 each; filaments slender, 12 mm. long, connate 4 mm. up from base; densely hairy in a band about the point of separation; stigmas oval. A flowering branch photographed April 29 appears in Fig. 18.

Fruit.—This variety is no exception to the rule that in apples variation in size of fruit is extreme. The majority of fruits on a given tree may present a uniform appearance, but examination brings out that the extremes are widely separated. Data on weight and size of 115 fruits of this variety are as follows:

Weight		*Longitudinal diameter*		*Transverse diameter*	
	gms.		*mm.*		*mm.*
Maximum	10.30	Maximum	25	Maximum	29
Minimum	1.22	Minimum	13	Minimum	14
Average	5.95	Average	20	Average	23

The form is roundish-oblate, sides usually equal; ground color of mature fruits is yellow, blushed with an over-color in shades of red; the more exposed fruits become bright scarlet, sometimes over nearly the whole surface, those less exposed are less covered with a dull brick-red. The variety is peculiar in that the colors of maturity are not assumed until very late in the fall; in this particular it is quite different from 806, the fruits of which are usually highly colored before fruits of 807 lose the green of immaturity. This variety is distinctly later than 806. It is from three to five days later in flowering in spring and the fruit is not mature until late fall. Even during the last days of October, after hard frosts, the fruits are much less highly colored than are those of 806.

Bloom is scanty, waxy, gray; skin smooth, polished, of medium thickness, tough; dots few, small, regular, round, inconspicuous; cavity shallow, broad, obtuse, sometimes ribbed; stem very long, 40 to 55 mm., slender, more or less clavate, erect, green, slightly pubescent;

basin shallow or none, often rounded up to the base of the calyx lobes, sometimes ribbed; calyx lobes of medium size, about 5 mm. long, obtuse, erect, connivent; calyx tube small, short, urn-shaped. This variety affords an excellent example of the inconstancy of the deciduous calyx lobes as a chief character distinguishing the forms of *M. baccata* and *M. toringo* from those of *M. prunifolia* and *M. malus*. October 20, 1915, the fruit of 5 trees was harvested, counted, each individual examined, and record made regarding calyx lobes as follows:

Total fruits	6,595
Calyx lobes deciduous and fallen	2,164 or 32.8 percent
Calyx lobes deciduous but still adhering	356 or 5.4 percent
Calyx lobes persistent	4,075 or 61.8 percent

The fruits of individual trees were not kept separate, but it was determined before harvesting that the proportions of fruits with deciduous calyx and those with persistent calyx, were approximately the same for the different trees. Those fruits in which the calyx lobes were deciduous possessed russet scars entirely similar to those on fruits of the variety 806. In those fruits having persistent calyx the lobes were in all cases enlarged and more or less fleshy at the base, appearing much as in Figs. 7, 8, and 11 of Regel's colored plate No. 364 facing page 208 in volume 2 of "Gartenflora,"[1] illustrating varieties of *Pyrus (Malus) prunifolia*. It has seemed singular to the writer that a character so generally accepted and used to separate definitely species and groups of species should exhibit the degree of inconstancy here appearing; an occasional fruit or flower departing, even in marked degree, from normal, is to be expected, as every botanist of experience knows, but here we have little more than

FIG. 19.—FRUITING BRANCH OF *M. baccata* (807), SEPTEMBER 16

Some of the fruits have deciduous calyx lobes, and in other fruits the lobes persist.

[1]Regel, Eduard. Gartenflora 2, 208. 1853.

one-third of more than 6,000 individuals retaining a character supposed to be constant for the species, while a little less than two-thirds exhibit the direct opposite, that is, persistent calyx lobes.

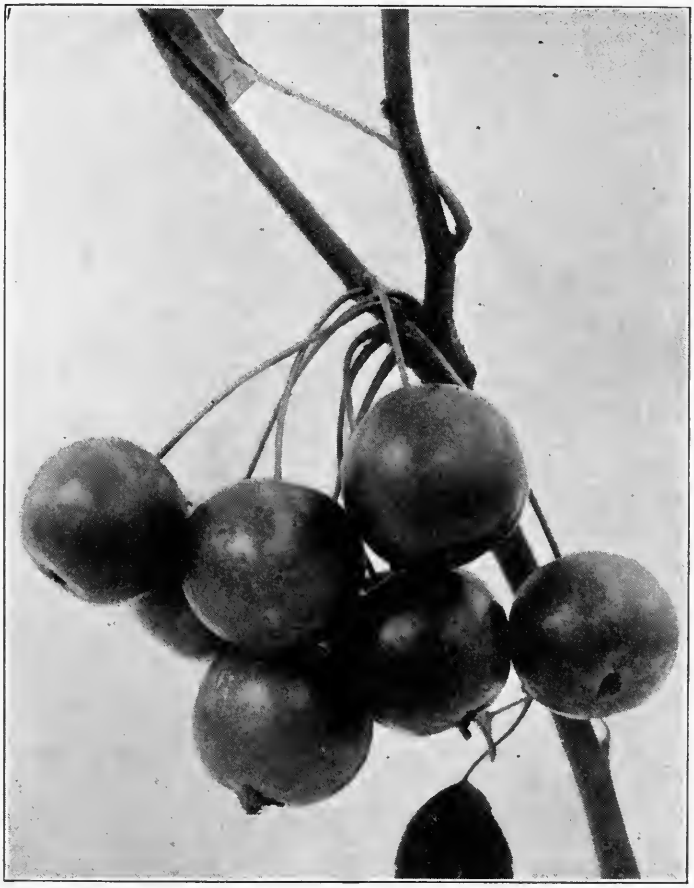

FIG. 20.—FRUIT CLUSTER OF *M. baccata* (807), SEPTEMBER 16
The same characteristic of deciduous and persistent calyx lobes is shown here as in Fig. 19.

But the finding regarding this character in its relation to this variety is not an isolated case; at least seven other species and varieties of Malus in our fruiting collection behave in the same way; they bear fruits with regularly deciduous calyx lobes and fruits in which the lobes persist mingled together on the same tree or even in the same cluster. I may add that this mixing of fruits having deciduous calyx lobes with those having persistent lobes is not confined to the supposed

wild or ornamental forms, but sometimes occurs in some orchard varieties of *M. malus*. In Wythe and Rome the calyx lobes are commonly persistent as in other varieties, but we have record of 16 fruits on one tree of Wythe and 3 fruits on one tree of Rome in each of which the calyx lobes were deciduous in the same manner and left the same kind of scar as in those species or forms described as having regularly deciduous calyx lobes. Fig. 19 shows a fruiting branch of No. 807 bearing some fruits having deciduous calyx lobes and others in which the lobes persist; the same characteristic is also seen in the single cluster appearing as Fig. 20. Core large, cordate, median, closed or sometimes half-open; core lines clasping, cells axile; carpels roundish-elliptical, entire, glabrous or sometimes tufted, concave; seeds plump, of medium size and brown color; flesh yellowish, firm, crisp, moderately juicy, acid.

7. *Malus baccata* var. (808)

Represented only in the 800 series by one tree now sixteen years old from root-graft made January 20, 1908, one tree now ten years old from graft made in 1914, and one tree on dwarf stock in greenhouse, now seven years old from graft of 1917. The older tree now has a height of 20¼ feet, a spread of 13 feet, and a trunk diameter of 7.1 inches.

Tree.—The strictly erect habit of growth, very large leaves, and smooth, light greenish-brown bark are the chief characteristics distinguishing this form from any other in the collection. Bark of two- and three-year-old wood light brown, bark of new shoots green; all more or less roughened by the numerous round or elongated lenticels. Over the lower part of the tree every bud on wood of the preceding year sends out a leafy spur imparting an appearance of density to the foliage; above, internodes are longer, the single leaves more remote, and the appearance more open.

Leaves.—Leaves from the short spurs are extremely variable in size and shape, from small round leaves 1 inch long to oblong-elliptical leaves 6 inches long and 2 inches wide; leaves from shoots of the current year are elliptical, 4 to 7 inches long and 2¾ inches wide terminating in long-acuminate points; crenate-serrate, glabrous both sides, dull dark green above, light green below; petioles 1¼ inches long, stout, very slightly pubescent, channel shallow; texture thin.

Flowers.—Produced in discontinuous masses from lateral buds on wood of the preceding year, only a part of such shoots flower; others produce leaves only, hence there is not that appearance of massed bloom that is characteristic of some other forms. No flowers are produced from spurs of interior or lower branches.

Flower buds 5 or 6 in each cluster, on slender pedicels 25 to 30 mm. long, sparsely pubescent, pink, fading to nearly white before anthesis;

just before opening the buds are oval in form, about 13 mm. long by 7 or 8 mm. broad. Flower expands 30 mm.; calyx lobes linear, acute, 8 mm. long by 2 mm. wide at base, scantily pubescent outside, densely pubescent within; in young buds the lobes are connivent, becoming erect and finally reflexed in open flowers. Petals obovate, rounded at apex, tapering at base to the claw, which is 2 mm. in length; stamens 14 to 18, filaments slender, the bases broadened, 6 to 8 mm. long; anthers plump, light yellow; styles 5, slender, somewhat clavate at apex, 8 mm. long, connate 1 mm. up from base, a few hairs about the point of separation; stigmas small, oval, oblique.

FIG. 21.—TREE OF *M. baccata maxima* (810)

This photograph taken in October illustrates the vigor and erect habit of the variety.

Fruit.—Roundish-oblate, vertical diameter 25 mm., transverse diameter 30 mm., yellow with bronze blush on side exposed to sun; pedicels 30 mm. long, slender, green, glabrous, cavity moderately deep, broad, obtuse, regular; basin rather deep, broad, smooth or somewhat ribbed; calyx tube short, broad, conical; calyx lobes regularly deciduous, all falling before maturity. The yellow fruit and the larger glabrous leaves are the chief distinctions between this form and the form under the number 806.

8. *Malus baccata maxima* (810)

Represented only in the 800 series. The variety is vigorous, producing erect, symmetrical trees, but has proved so susceptible to blight that it cannot be recommended for breeding or for ornamental planting. The trees grafted in 1908 have all been killed by blight and only four trees from grafts made in 1914 now remain to represent the variety in the collection. These trees now in their eleventh year have escaped disease; they average 14 feet in height, 11 in spread, and have an average trunk diameter of 4.3 inches. In the years 1913 to 1917 the variety was used as female in ten crosses, seven of which are now represented by trees from six to ten years old in orchard. In the same years it was also used as the pollen parent in eleven crosses, and seven of these crosses are now represented in orchard. These hybrid trees have not

escaped blight entirely but have not shown the susceptibility to the disease that has developed in the *baccata* parent.

Tree.—The vigor and erect habit is expressed in Fig. 21 from a photograph of a perfectly healthy tree as taken in October. Bark of the trunk is light yellowish-brown, smooth; bark of twigs is light reddish-brown; lenticels are few, small, mostly round, inconspicuous.

FIG. 22.—TWIG OF *M. baccata maxima* (810) IN BUD, APRIL 21

Leaves.—Those from mixed buds on flowering shoots are small, 1 to 2 inches long, ovate to lanceolate, densely white tomentose; mature leaves are from 3 to 5 inches long, 1 to 2 inches wide, elliptical, oblong, or ovate; accuminate, crenate-serrate, glabrous both sides, rather dull dark green above, lighter below, smooth, texture thin, limp, often drooping; petioles slender, 1 to 1¾ inches long, glabrous, narrowly and deeply channelled, stipules small, linear, soon disappearing.

Flowers.—Produced profusely from terminal and lateral buds of terminal shoots and to some extent from terminal buds of short spurs; buds light pink when young, fading to pure white before opening; as they approach anthesis the buds appear long, slender, and pointed. Flowers expand from 25 to 30 mm. Calyx lobes triangular, pubescent both sides; petals oval, 15 mm. long, 9 mm. wide, rounded at apex, abruptly rounded at base to the short but distinct claw, pure white; anthers plump, light yellow; styles slender, 9 mm. long, connate 1½ mm. at base, copiously hairy in a band 3 mm. wide beginning 1 m. from base and extending above the point of separation; stigmas capitate, oval. Fig. 22 showing a twig in bud is from photograph taken April 21.

Fruit.—Round or slightly oblate. Weight, longitudinal, and transverse diameters as determined from 82 fruits are as follows:

Weight	*gms.*	*Longitudinal diameter*	*mm.*	*Transverse diameter*	*mm.*
Maximum	11.66	Maximum	25	Maximum	28
Minimum	1.34	Minimum	13	Minimum	16
Average	8.38	Average	20	Average	23

Ground color yellow with blushed over-color, usually light red but in some much exposed fruits becoming quite dark; on the other hand some fruits are yellow with no more than a pinkish blush; bloom scant, waxy, white; skin smooth, polished, tough, of medium thick-

FIG. 23.—FRUITING BRANCH OF *M. baccata maxima* (S10), SEPTEMBER 1

ness; dots few, small, regular, round, white, or sometimes russet; cavity deep, medium to broad, acute, regular; stem slender, 27 to 36 mm. long, green, somewhat ribbed, calyx lobes regularly deciduous; calyx tube short, small, conical, often with projecting pistil point.

9. *Malus baccata oblonga* (811)

Propagation of this form by root-grafts in 1908 was unsuccessful; but some of the scions top-worked on a Sops of Wine tree grew with

reasonable vigor. In 1911 scions from this tree were worked on both paradise and Doucin stocks in pots for use in the greenhouse. One tree on Doucin stock survived, has fruited each spring since 1913, and tho still small, is perfectly healthy. In 1913 Yellow Transparent pollen was used on 49 flowers; 48 fruits matured and thirty-two seedlings now ten years old are living in orchard. In the years 1914, 1916, and

FIG. 24.—POTTED TREE OF *M. baccata oblonga* (811) ON DOUCIN STOCK

1917, seven other crosses were made and forty-six trees from crosses by Akin, Delicious, and the crab form No. 830, carried as *M. malus* var. are now in orchard at seven and nine years of age. The variety was used as the male parent in three crosses involving twenty-eight pollinations, but two of the crosses failed and the third, on Akin, produced only one fruit from eleven pollinations. Only one seedling from this cross survives; it is seven years old. Crosses with this variety as the mother parent were more successful than where it was used as the

pollen parent. Having no tree upon its own roots or upon a stock other than dwarf, it is not possible to give habit of the variety as a standard; from observation of growth of top-grafts, both on ordinary stocks and on Doucin, it appears that the natural trend of branches is obliquely upward, giving a tree somewhat less erect than is No. 806, but not inclined to spread as much as does the variety No. 807. *M. baccata oblonga* on Doucin stock as it appeared June 21, 1916, is shown in Fig. 24. The tree was at that time 3 feet high; at this time, eight years later, it measures 5½ feet in height, 2½ feet in spread, and has a trunk diameter of 1⅛ inches. Bark of older wood light gray, of new shoots, green, becoming light brown as they mature; internodes 1¼ to 1½ inches long, lenticels rather numerous, mostly elongated.

FIG. 25.—TWIGS OF *M. baccata oblonga* (811), PHOTOGRAPHED IN GREENHOUSE, FEBRUARY 24

Leaves.—3¼ to 5½ inches long, 1½ to 2 inches wide, ovate to elliptical, lower mostly obtusely rounded at apex, upper acuminate, irregularly doubly serrate, smooth, glabrous both sides, glandular along the ribs above, dark green above, somewhat lighter below; texture thin, limp; petioles stout, 1¼ to 2¼ inches long, glabrous; stipules ½ to ¾ inch long, lanceolate, serrate, inclined to persist.

Flowers.—From terminal and lateral buds on wood of the preceding year; young buds pink, fading to nearly white before opening; flowers expand 32 mm.; pedicels slender, variable in length, between 19 and 32 mm., glabrous; calyx lobes narrowly triangular, acuminate, 11 mm. long, 1½ mm. wide at base, glabrous outside, pubescent within; petals 5, oval, 17 mm. long by 11 mm. wide, rounded at apex, white, slightly tinged pink, claw short but distinct, about 1 mm. long. Stamens 16 to 20, filaments slender, 6 to 8 mm. long; anthers small but plump, light yellow; styles mostly 5, in some flowers 4, slender, 12 mm. long, hairy at base, somewhat flattened at apex; stigmas oval, oblique. Twigs in buds as photographed in greenhouse February 24, appear in Fig. 25.

Fruits.—Smaller than in any other variety of *baccata*. Fifty fruits weighed and measured ranged as follows:

Weight		*Longitudinal diameter*		*Transverse diameter*	
	gms.		*mm.*		*mm.*
Maximum	2.70	Maximum	16	Maximum	16
Minimum	.54	Minimum	9	Minimum	8
Average	1.41	Average	12	Average	13

Notwithstanding the fact that averages of the two diameters indicate a round or even slightly oblate form, the majority of fruits appear distinctly oblong as in Fig. 26; base regular, rounded, apex flattened, regular or in some fruits somewhat ribbed; sides equal. The majority

FIG. 26.—FRUITS OF *M. baccata oblonga* (811)
The majority of fruits are distinctly oblong.

of fruits are yellow with a red blush, but some are entirely yellow and others have the yellow entirely overlaid with red, which varies thru light shades to rather dark; bloom scant, waxy, gray; skin smooth, polished, tough, thin; dots many, small, russet or sometimes white; cavity medium in depth and breadth, acute, regular; stem long, 26 to 45 mm., slender, erect, green, glabrous; basin shallow, broad, obtuse, often slightly ribbed; calyx lobes uniformly deciduous; calyx tube small, short, conical; core large, closed; cells 4 to 6. Of 29 fruits examined 10 had 4 cells each, 18 had 5 each, and 1 had 6 cells.

10. *Malus baccata sanguinea* (813)

Represented by three trees now sixteen years old from root-grafts made in 1908 and by several trees grafted in 1912 and 1914. The trees are healthy and of reasonable vigor, but have rather open tops with

foliage less dense than in a number of other forms; this appearance of openness is due mainly to the preponderance of small leaves. The older trees average 22 feet in height, have an average spread of 23 feet, and a trunk diameter of 7.6 inches. The habit is somewhat spreading, resembling 807, but of less vigorous appearance because of the smaller leaves. Bark of trunk is light grayish-brown; of twigs dark greenish-brown. Leaves 1½ to 5 inches long, ¾ inch to 2 inches wide, elliptical or lanceolate, some of the smaller roundish-oblong or ovate, generally acute, but the smaller mostly obtuse, crenate-serrate; glabrous above, very scantily pubescent below, dull dark green above, somewhat lighter below; petioles 1 inch long varying from slender to stout, slightly pubescent, channeled. Texture thin, limp. Some leaves are as large as any on 807, but the proportion of small leaves is greater, giving the general appearance of having less foliage. The flowers were borne from terminal buds of short spurs; there were none on terminal shoots of the preceding year.

Leaves.—Those from mixed buds are small, ovate, acute, serrate, scantily pubescent below, and with a few short hairs along the midrib above, color a medium green. Buds globular, 6 to 7 in a cluster, dark pink; pedicels slender, 25 mm. long, pubescent, green; ovaries green, pubescent.

Flowers.—Expand 30 mm. Calyx lobes 5, triangular acuminate, 6 mm. long, 2 mm. wide at base, both sides closely pubescent, green, tips somewhat reflexed even in bud; petals oval or nearly round, 15 mm. long by 13 mm. broad, claw 1 mm. long, mostly pale pink, but with darker pink in spots on the outside, especially about the base; stamens 20, filaments slender, 5 to 8 mm. long, anthers plump, light yellow. Styles 5, slender, 10 mm. long, tips flattened and surmounted by the irregularly oval, oblique stigmas, connate 1½ mm. at base, glabrous at base, but hairy about the point of separation and continuing a short distance above. The hairs are shorter and less numerous than in some other forms.

Fruits.—Roundish, many of them appearing to the eye as distinctly oblong, but in every specimen measured the transverse diameter exceeds the longitudinal diameter from 3 to 9 mm., which points to oblate as a proper designation of form. Averages of weight and size as determined from 179 fruits are: weight 35.32 grams; long diameter 39 mm.; transverse diameter 44 mm. Base regular, rounded; apex irregular, ribbed, cross-section irregularly ribbed, sides equal. Color a clear yellow which darkens to nearly orange where exposed to direct sunlight; immature and shaded fruits are greenish-yellow or sometimes whitish-yellow; red appears to be entirely wanting; bloom scanty, scarcely perceptible; skin smooth, polished, thin, tough; dots few, small, round, white, scattered, inconspicuous. Cavity medium in depth to deep, rather narrow, acuminate, regular; stem slender, 21 to 25 mm.

in length, clavate, erect or often oblique, green, scantily pubescent. Calyx small, pubescent, closed. Basin shallow to medium in depth, rather narrow, obtuse, irregular, ribbed; calyx lobes small, rather shortly acute, sometimes reflexed, sometimes connivent; calyx tube small, short, conical. Core of medium size, cordate, oblate, distant, closed, stamens marginal, core lines clasping. Cells axile, of uniform size; carpels are mostly obovate, but in some fruits ovate, commonly entire, but often emarginate, glabrous, moderately concave. Seeds plump of medium size, short and broad in form, medium brown in color. In 1917, after a cool, wet summer the fruits began ripening and

FIG. 27.—FRUITS OF *M. baccata sanguinea* (813) NATURAL SIZE

falling about the first of September. Doubtless a hot summer would bring them to maturity a week or two earlier. In seed production the fruits of this form of Malus far exceed those of any other crab form examined. The 179 fruits analyzed bore 1,563 seeds, an average of 8.73 to each fruit; this is more than double the average for the crab group, while only about one-third of the orchard varieties, for which record has been made, equal or exceed this average. The range in seeds to each fruit is from 6 to 11 and the distribution is as follows; with 6 seeds each 7, with 7 each 17, with 8 each 38, with 9 each 74, with 10 each 41, and with 11 each 2. Flesh of the fruit is white, firm, crisp, moderately juicy, subacid, and of agreeable flavor. That this form of Malus appears under a name that does not belong to it is evident from

its character; its affinities do not lie with *M. baccata,* as is shown by the regularly persistent calyx lobes and the relatively short pedicels, and certainly there is nothing to suggest *sanguinea* as a varietal name. In habit of growth and foliage it suggests *M. prunifolia,* but the fruit is widely different from that of any of the forms of prunifolia now in the collection. Definite determination of its proper systematic position cannot be made at this time. A fruiting branch as photographed, natural size, is shown in Fig. 27. This form has been used in only one cross; flowers pollinated by Collins in 1917 yielded 84 fruits representing over 57 percent of the pollinations. From seeds of these fruits there are in orchard 287 seedlings, now in their seventh year; none have yet fruited.

11. *Malus baccata sieboldi* (814)

Only one of ten root-grafts made in 1908 has survived; this is now at sixteen years of age, 14 feet high, has a spread of 13 feet, and a trunk diameter of 4.1 inches. Branches are ascending, forming a fairly symmetrical crown; bark of trunk and branches light grayish-brown, twigs of the current year green.

Leaves.—Two to 4½ inches long, ¾ to 2 inches broad, elliptical or oval, accuminate or acute, crenate-serrate, glabrous both sides, light green above, still lighter below; petioles stout, ¾ to 1 inch long, glabrous, stipules lanceolate, entire, petiolate, persisting.

Flowers.—Produced from terminal and lateral buds of terminal shoots and from terminal buds of short spurs. Pedicels slender, green, 1 inch long, glabrous; ovary green, glabrous. Calyx lobes 5, triangular acuminate, 6 mm. long and 2 mm. wide at base, glabrous without, closely and finely pubescent within. Flower expands 28 mm. Buds light pink fading to pure white as flowers open; petals oblong or nearly orbicular, 12 mm. long by 10 to 11 mm. wide, rounded at apex and base, claw very short. Stamens 18, filaments slender, 5 to 8 mm. long, anthers plump, light yellow. Styles 5, slender, 11 mm. long, connate from base for 2½ mm., glabrous for 1½ mm., and then hairy to just above the point of separation. Stigmas oval, oblique.

Fruit.—Small, round or roundish, yellow with bronze blush in the sun; cavity shallow, broad, basin a very slight depression within the limits of the circular russet scar left by the deciduous calyx lobes; pedicels slender, 12 to 20 mm. long, green, glabrous. (Fig. 28.)

This variety of *M. baccata* has been used as female in three crosses. In 1913, pollen of Fanny was used on 13 flowers; the attempted cross failed. In 1916 from flowers pollinated by Oldenburg 100 fruits matured; these represented about 28 percent of the pollinations; from these fruits 279 seedlings were planted in nursery and in 1924, the eighth year, 218 are living and are rated as 65 percent "good," 22 percent "fair," and 12 percent "poor." The largest tree is 10

feet 3 inches high, has a spread of 7 feet 3 inches and a trunk diameter of 2½ inches; the smallest tree is 8 inches high, has no spread, and a diameter of only .2 inch. The average is a tree 6 feet high with spread of 3½ feet, and a trunk diameter of 1.3 inches. Forty-nine of the trees began flowering this season (1924) and some of these are maturing fruits. In 1917 Longfield pollen was used on 96 flowers; the pollin-

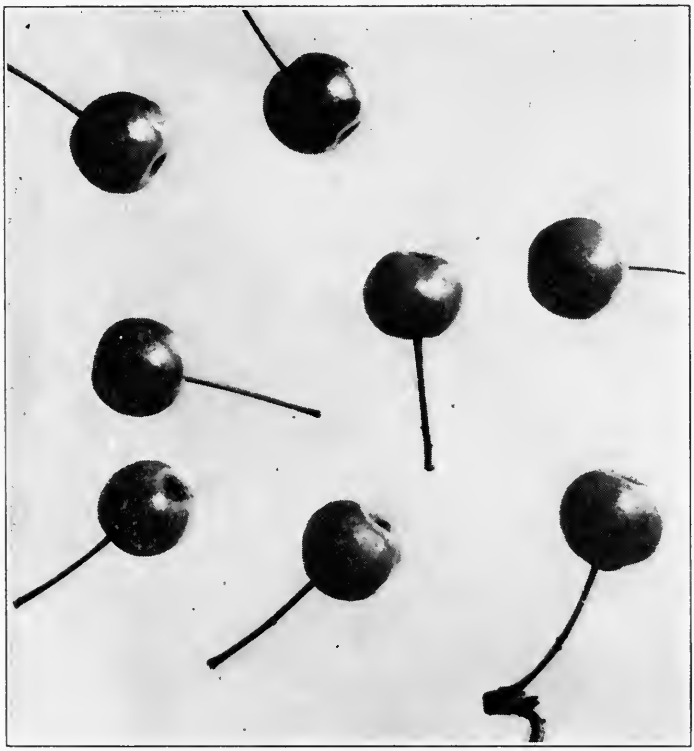

FIG. 28.—FRUITS OF *M. baccata sieboldi* (814)

These fruits are small, round, and yellow, showing a bronze blush in the sun.

ations were 12½ percent successful and from these fruits there are in orchard fifteen trees now in their seventh year; none of these have flowered. The rating of the trees is fourteen "good," and one "fair." Height ranges between 4 and 8 feet with an average of 5½ feet; the average spread is 4 feet and the average diameter 1.3 inches.

This variety was used as the pollen parent in four crosses, all in the year 1914. On Ben Davis the pollinations were 10 percent successful; on Shackleford 32 percent successful; on Winesap 6 percent

successful; on Black Ben Davis one fruit matured from 48 pollinations but the fruit contained no viable seeds. From the three other crosses there are in orchard eleven trees of the Ben Davis cross, twenty-five of the Shackleford, and nine of the Winesap cross. The seed content of fruits from these crosses was good, averaging 7 to each fruit; germination averaged 60 percent, but in each group there was a large proportion of weak seedlings that died at intervals until the trees remaining represent only 44 percent of the germinations. The trees living have each year improved in grade until nearly all now rank as good. Four of the nine Winesap, twelve of twenty-five Shackleford, and eight of eleven Ben Davis have fruited. Fruits are all crab-like, intermediate in size between fruits of parents, but always nearer the crab-parent.

12. *Malus cashmerica*

Scions of this form were received in each of the three series. With the scions received in 1907 under the number 19640 was this note appearing in the list, "is a Himalayan species. It is growing well at the Arnold Arboretum and is interesting as one of the few Himalayan trees that flourish in that climate." Root-grafts were made but none lived. Scions received in 1908 were grafted both as root-grafts and top-grafts, but again all failed.

Scions received in 1912 were worked as root-grafts and also as top-grafts on paradise and Doucin stocks in pots. A number of these grafts succeeded and there are in orchard four root-grafted trees, now in their thirteenth year. For use in the greenhouse are three trees on dwarf stocks; these are now eleven years old.

The four trees in orchard are healthy vigorous trees that have never been attacked by blight; they are upright, approaching pyramidal in form; average height is 22 feet, spread 14 feet, and trunk diameter 7.07 inches. Bark of older wood light gray, of young twigs reddish-brown; lenticels few, small, round, light russet.

Leaves rather small, 1½ to 3½ inches long, by ½ to 1¼ inches wide, oval or elliptical, acute, serrate; some of the upper leaves on new shoots are three-lobed; all are glabrous above and scantily pubescent below; light green, the lower surface only slightly lighter than the upper; petioles ¾ to 1¼ inches long, slender, pubescent, red; stipules short, lanceolate, serrate, petiolate.

Flowers.—Buds are deep red, fading to pink as flowers are ready to open, oval, becoming somewhat elongated; flower expands 23 mm.; pedicels rather stout, 18 mm. long, pubescent; calyx lobes triangular, acuminate, pubescent both sides, 4 mm. long, erect in bud, becoming horizontal in open flowers; petals 5, oval, 12 mm. long by 6 mm. wide, claw short, apex rounded, white with irregular pink areas; stamens in flower examined, 15, filaments slender, 4 to 6 mm. long, anthers plump,

light yellow; styles 5, slender, 9 mm. long, distinct nearly to the base, pubescent in a band about the point of separation, stigmas capitate, irregularly round.

Fruits.—Round or slightly oblate, base irregular, flat, apex irregular, slightly conical, ribbed in cross-section, sides equal. Six fruits examined average 17 mm. in vertical diameter, 19 mm. in transverse diameter, and have an average weight of 2.33 grams. Color orange-yellow, bloom scanty, waxy, white; skin smooth, thin, tough; dots few, of medium size, round, white, scattered, inconspicuous; cavity shallow, broad, obtuse; stem slender, 11 to 25 mm. in length, erect, smooth,

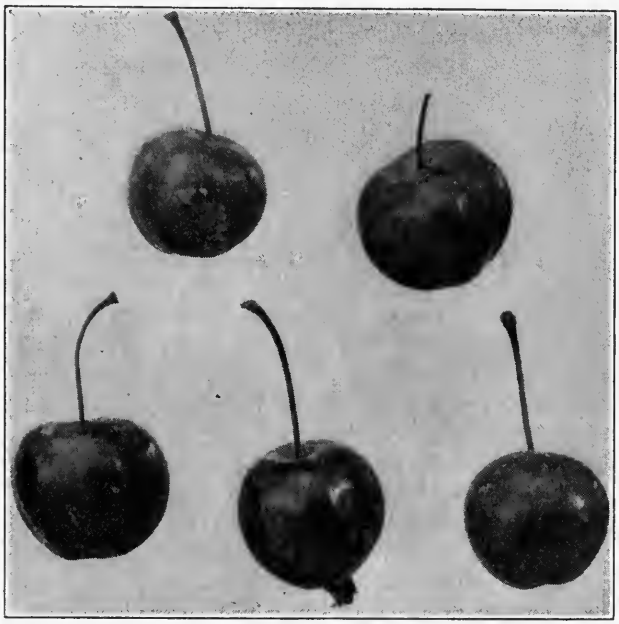

FIG. 29.—FRUIT OF *M. cashmerica* (1207), NATURAL SIZE

green more or less streaked with red. Calyx lobes deciduous in 5 fruits, persistent in 1, lobes are of medium size, rather short and broad, acute, erect. Basin, in those fruits having deciduous lobes, shallow, moderately broad, obtuse, irregularly ribbed; the fruit with persistent lobes has no basin; bases of the lobes are fleshy and the tips connivent; calyx tube short, small, conical. Core of medium size, cordate, median, closed; stamens marginal, core lines clasping, cells uniform, axile; carpels elliptical, glabrous, moderately concave; seeds of medium size, plump, light brown. Flesh yellow, firm, crisp, juicy, acid, astringent. Five of the fruits appear, natural size, in Fig. 29.

With *M. cashmerica* as the female parent three crosses were made in the greenhouse in 1917; these crosses were by Fanny with four pollinations yielding four fruits; by Jonathan with twenty-one pollinations, yielding twenty-one fruits, and by Delicious with twenty-two pollinations yielding ten fruits. The three crosses are now represented in orchard by four seedlings from the Fanny cross, sixty-four from the Jonathan cross, and nineteen from the Delicious cross. These seedlings have grown with reasonable vigor, but none have yet flowered. The same season pollen of *M. cashmerica* was used in four crosses; eight pollinations on Delicious and nine on Grimes failed; eight pollinations on Grimes yielded 1 fruit from which four seedlings are growing, and nineteen pollinations on Jonathan matured 5 fruits from which twenty-three seedlings are in orchard. As the female parent pollinations were nearly 75 percent successful, but used as male the success percentage was a little less than 14 percent. Additional crosses may give quite different results, but the success when used as the mother commends the species as a good breeder.

13. *Malus crataegifolia* (817)

Scions of this species were received in each of the three series. With the scions received in 1907 as No. 19632 was this note, "sometimes called Cormus, is a rare Italian tree." Three root-grafts made in 1907 failed. Scions received in 1908 were propagated under the number 817, only two of the grafts lived; one of these died in 1910, the other in 1911. Scions received in 1912 were grafted, in part on paradise and in part on ordinary apple stocks, but none survived beyond the second year. The only representation of the species now living is a small tree on paradise propagated in 1911 from one of the root-grafted trees of 1908. This species does not seem adapted to any of the stocks upon which we have attempted to propagate it and doubtless will soon pass out of the collection. The plants grown have red twigs and small leaves that resemble those of species of crataegus.

Leaves mostly 1½ inches long, ovate in outline, variously lobed and indented, the ultimate teeth sharp-pointed, glabrous above, pubescent below; yellowish-green; probably not normal in either color or size; petioles ½ inch long, stout, pubescent.

14. *Malus coronaria* (L) Mill.

Pyrus coronaria Linnaeus Spec., ed. 1, 480. 1753.
Malus coronaria Miller's Dictionary, ed. 8, 2. 1768.

Scions received under the number 19641 in 1907 were worked as both root- and top-grafts, but none lived. Scions received in 1908 and worked as root-grafts on apple seedling stocks also failed to grow. On April 4 of that year seventeen scions were top-grafted on a Sops of

Wine as stock; thirteen of the scions lived and grew vigorously. These grafts continued growth, forming a spreading crown. Late in the winter of 1913 the tree was moved to another area and that spring flowered profusely; late in the summer the trunk of the stock was attacked by blight and the tree died early in the summer of 1914. Scions worked on paradise stocks in 1910 died during the summer of 1911. Early in 1911 scions were top-grafted on potted Doucin stock; these grew; the tree was plunged in open ground each summer and forced under glass each winter. The tree flowered sparingly in 1914 and more abundantly in succeeding seasons.

FIG. 30.—TREE OF *M. coronaria* (818) IN POT ON DOUCIN STOCK

This tree was from graft of February 24, 1911, and was 21 inches high when photographed June 21, 1916.

In 1912, a number of root-grafts were made, using scions from the top-grafted tree and apple seedlings as stocks; ten of these grafts lived thru 1912, but only four lived to be planted in orchard in 1914; these made feeble growth during the three following seasons and then died. With the single exception of the scions top-grafted on Sops of Wine in 1908, all of the grafts made very feeble and unsatisfactory growth. As an example attention is called to Fig. 30 from a photograph made June 21, 1916, of the tree from graft of February 24, 1911, on potted Doucin stock. The tree when photographed was 21 inches high; the annual increment increased each year, but was very small for all years. In 1915 a branch 14 inches long terminating in a fruit bud was thrown out; in March, 1916, this terminal bud, together with several lateral buds on the same branch and one short spur just above the union, put forth flowers; these were emasculated and in due time pollinated; 3 fruits resulted. From an upper lateral bud an extension branch over 10 inches long has grown and from the main stem is another shoot 6 inches long; these extensions are for the sixth year in the life of the plant and indicate additional

vigor, rather than that the spring flowering was a dying effort. This is not a case of scion over-growing the stock, for there is no enlargement about the union, which is fairly smooth; nor does it appear that the stock is of too rapid growth, for its diameter has increased by very small increments. That there is tolerance between stock and scion is evidenced by endurance of life, but that they are congenial is denied by the feeble growth. Considering the experience with all the grafts it appears that *M. coronaria* rejects the paradise and roots of mongrel seedlings as stocks, accepts the Doucin with reluctance, and is most at home on the branches of a free-growing orchard variety. The breeding collection contains no tree of normal growth, but campus specimens indicate an open, wide-spreading top, with rigid branches.

Leaves.—Variable; the most common form is broadly ovate, rounded, subcordate at base, obtuse at apex, 3 to 3½ inches long by 2½ to 3 inches wide, irregularly incisely serrate, or occasionally more or less lobed; other leaves are oval, obovate, or some of the smaller nearly orbicular in outline, tapering somewhat abruptly at base; apex either rounded or in some leaves acute. All leaves are glabrous above, scantily pubescent below; petioles short, ¾ to 1 inch long, stout, pubescent, channel deep and very narrow, reddish-brown. Early in the season the leaves are bright green; later they become dull dark green or even brownish, the lower surface somewhat lighter grayish-green.

Flowers.—Produced from terminal and lateral buds on shoots of the preceding year, and from terminal buds of short rigid spurs; 5 or 6 flowers and from 4 to 7 small leaves from each mixed bud. The species is peculiar in its inflorescence in that the bud axis elongates, often to 1½ inches in length, thus approximating a raceme. In the lateral cluster taken for description the axis is 1⅜ inches long; the 2 lower leaves are separated by ¼ inch and show nothing in the axils, the third leaf has, in the axil, a small leafy shoot with 2 leaves; the fourth and fifth leaves each have a flower pedicel in the axil and the points of insertion are separated ⅜ inch; ⅛ inch above the last leaf is another pedicel and about ⅛ inch above this is the final division into 2 pedicels; from the insertion of the lowest of the 5 pedicels to the point of final division is ¾ inch. Fig. 31 is a bud cluster showing elongation of axis.

Buds are, at first, globular, becoming oval or obovate as they approach anthesis, bright pink, fading to very light pink before opening. Flowers expand 1¼ to 1½ inches. Pedicels, the lower 1½ inches long, upper 1⅛ inches long, slender, pubescent, each bearing 2 linear, attenuated brown bracts; upper part of ovary and outer surface of calyx lobes glabrous. Calyx lobes 5, triangular, acute, 4 mm. long, pubescent on margins and inner surface; petals 5, imbricated above, but not below; when fully expanded they are projected out so far by the long slender claws that there is no imbrication, each petal stands distinct by itself; obovate or nearly orbicular in outline, 12 mm. long

by 9 mm. wide, pink, little lighter than when in bud, but eventually fading to nearly white. Stamens 20, filaments slender, but short, 5 to 8 mm. long; anthers large, of long form and mostly tapering to an acute point, light red. When anthers dehisce the pollen inclines to cling to anthers and such as is separated remains in masses; styles 5, slender, 10 mm. long, light red, connate one-third the length, hairy

FIG. 31.—BUD CLUSTER OF *M. coronaria* (818), MARCH 11, SHOWING ELONGATION OF AXIS. FIG. 32.—TWIG IN BUD, MARCH 15

This species is late flowering, the buds developing with less rapidity than in most other forms of Malus.

with long, white, massed hairs from base to just above the point of separation. Buds develop with less rapidity than in most other forms of Malus and the species is late in flowering. Fig. 32 is a branch in bud as photographed March 15.

Fruit.—Records include only 5 specimens developed from hand pollinations in the greenhouse, 2 in 1914 and 3 in 1916. These fruits range in weight from 38½ grams to 54½ grams with an average of 44.6 grams; in vertical diameter from 34 to 41 mm. with an average of 37 mm. and in transverse diameter from 37 to 53 mm. with an average of 47 mm. Form distinctly oblate, sides equal, base irregular, rounded, apex irregular, flat, cross-section ribbed, dark green; bloom heavy, waxy, gray; skin smooth, unctuous, thick, tough; dots few, mostly about the apex, medium in size, round, white, inconspicuous; cavity shallow, medium in width, obtuse, regular; stem varying in length from 40 to 54 mm., slender, erect, green, smooth; basin deep, moderately broad, acute, irregular, ridged. Calyx closed, lobes of medium size, long-slender, acuminate, erect, separated; calyx tube large, cylindrical. Core of medium size, oblate, median, closed; stamens me-

dian; cells axile, uniform; carpels elliptical, emarginate, glabrous, concave; seeds large, plump, dark brown. Flesh white, firm, crisp, juicy, very acid, very fragrant. Two fruits as photographed September 28 are shown in Fig. 33.

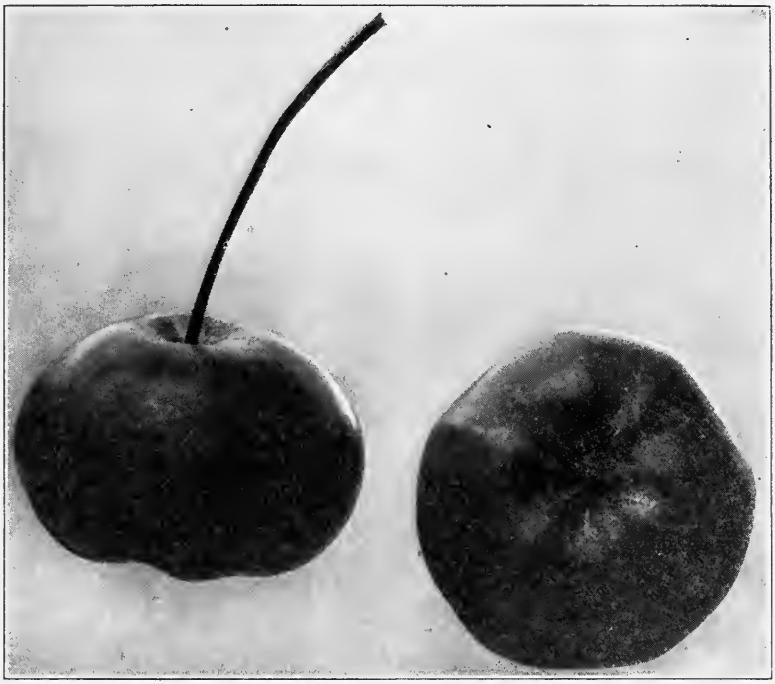

FIG. 33.—FRUITS OF *M. coronaria* (818) PHOTOGRAPHED SEPTEMBER 28, NATURAL SIZE

Opinions regarding the fragrance and the economic value of the fruit are various. According to Miller's Dictionary,[1] "The fruit is small, sour, and unfit for anything but to make vinegar of. It lies under the trees all winter, acquires a yellow color and seldom begins to rot until spring comes on." Pursh[2] says: "The *Sweet-scented* Crab-tree the fruit of which is well known as a most excellent preserve for the table, is a very fine ornamental tree, not only for the beauty, but particularly for the fine violet-scent of its flowers." In Edwards' Botanical Register,[3] this characterization is given: "... The crab or apple is small, yellowish-green, austere, with a strong disagreeable smell; is used in confectionery and where abundant is sometimes made by the

[1]Miller's Dictionary 2, part 1. 1807.
[2]Pursh, Frederick. Fl. Amer. Sept. 1, 340. 1814.
[3]Edwards. Bot. Reg. 8, 651. 1882.

American farmers into tolerable cider. . . . Introduced (in England) by Mr. Robert Furber in 1724." Dr. Sargent[4] says in describing the fruit, "deliciously fragrant." The writer recalls boyhood experience with the extreme acidity and utter unpalatable condition of the fruit as found in forest glades in late autumn, and also remembers the characteristic fragrance which was as much appreciated as was that of the flowers in the late spring. Several writers on the breeding of apples have suggested use of the native crabs as starting points in breeding work, but I have been unable to find any record of actual breeding, or reports of the performance of native crabs when used as parent plants. If there is any virtue in our native crabs for breeding purposes, the degree of utility should be ascertained and this is possible only by actual use of the various forms as parents in crosses. Effort has been made at this Station to test the native forms as well as established varieties and foreign forms of the genus.

M. coronaria has not been represented by flowering trees in orchard, but one dwarf has flowered in the greenhouse and it has been used in crosses both as female and as male. As the female parent, flowers pollinated by pollen of Yellow Transparent, Stayman Winesap, Akin, and Twenty Ounce failed in production of fruit; a 1914 cross by Oldenburg matured 2 fruits from twenty-five pollinations, these fruits contained 7 seeds, 2 of which germinated but were too weak to live and promptly died. In 1916, 14 flowers pollinated by Delicious matured 3 fruits which contained 9 seeds; 3 of the seeds germinated and two seedlings are living in this their eighth year; one is 2 feet high, the other 9 inches high, and both are graded as "poor." In 1917 another cross involving 15 flowers pollinated by Jonathan was made; this yielded 5 fruits containing 13 seeds, 7 of which germinated; three seedlings, now in their seventh year, are living; they have an average height of 1 foot 10 inches, and an average diameter of .33 inch; one is graded "fair," and two as "poor." Thus the net result of pollination of 74 flowers in seven crosses having *M. coronaria* as the female parent is five seedlings seven and eight years old, four of which will certainly die within the year and the fifth is too feeble to encourage the hope that it may live to fruiting.

Pollen of *M. coronaria* was used in seven crosses as follows: on Yellow Transparent, Akin, Winesap, Stayman Winesap, Malus Soulardi, Grimes, and Twenty Ounce; the first five failed entirely; Twenty Ounce from six pollinations matured 1 fruit, but this fruit was seedless. Two pollinations on Grimes matured 1 fruit which contained 2 seeds, both of which germinated; one seedling was planted in nursery and is now living in orchard in its eighth year. It is a fairly vigorous tree and grades as "good," it is 5 feet 7 inches high, has a spread of 5

[4]Sargent, C. S. Silva N. Amer, 4, 71. 1892.

feet and a trunk diameter of 1 inch. Appearance of this tree warrants the prediction that it will live to produce fruit. It is the one thing that saves *M. coronaria* from total failure as a parent in breeding.

15. *Malus dioica* (819)

Malus non florens, fructificans tamen Bauhin Pin., 435. 1671.
Pyrus apetala Münch. Hausv. 5, 247. 1771.
Pyrus dioica Moench Verz. 87. 1785.
Pyrus dioica Linnaeus Spec., ed. 5, Willdenow Spec., 1018. 1797.
Pyrus dioica Miller's Dictionary, ed. 9, 2. 1807.
Malus dioica Audibert Cat.

Description as given in Miller's Dictionary[1] is as follows: "Leaves oval, serrate, flowers solitary dioecious, petals linear the length of the calyx. It is supposed that this may have sprung from the common apple. The leaves are pubescent underneath. Peduncles one-flowered at the axils of the leaves towards the end of the branches, forming a sort of umbel. Petals yellowish-green. Styles five, filiform, smooth; with club-shaped stigmas. Willdenow did not observe any stamens."

J. C. Loudon[2] records the species as below:

"*P. (M.)* dioica W. The dioecious-*sexed* Apple Tree.

"*Identification.* Willd. Arb., 263; Spec., 5. p. 1018.; Dec. Prod., 2. p. 635.; Don's Mill., 2. p. 646.

"*Synonymes. P.* apétala *Münch. Hausv.*, 5. p. 247., on the authority of Willdenow; Màlus dioica *Audib. Cat.*"

"Leaves oval, serrated, tomentose beneath. Flowers, in many instances solitary. Sexes dioecious by defect. Calyx tomentose. Petals linear, the length of the sepals. Styles glabrous (*Dec.Prod.*II., p. 635). Cultivated occasionally in gardens on the Continent; but we have not seen it in Britain."

The references to this species that have thus far been found are:

Index Kewensis 2, 669. 1895.
Pyrus dioica, Moench Verz. 87. (1785) = *Pyrus malus.*

From these it appears that this pistillate form of apple has been known at least as far back as the seventeenth century. Martyn (1807) supposes it to be derived from the common apple, and the "Index Kewensis" rates it as a synonym of *Pyrus (Malus) malus.* No staminate form is mentioned and in all probability there is none. It is not a truly dioecious form, but dioecious by defect, as is pointed out by Loudon. The stamens are entirely wanting, making this a pistillate form in the same manner as certain varieties of strawberries are pistillate. The leaves and fruit suggest the common apple and it may be readily accepted as a form of *Malus malus.*

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[1]Miller's Dictionary 2, part 1. 1807.
[2]Loudon, J. C. Arboretum et Fruticetum Britannicum 2, 892. 1838.

M. dioica is represented in the Station plantation only in the 800 series under the number 819. Ten root-grafts on apple seedlings were made January 18, 1908; five of these trees were planted in orchard in 1910, grew vigorously until 1916, were then attacked by trunk blight and died the next year. In a general way growth of the trees was erect, but one was markedly irregular in the direction of branches; lower branches were long and straggling and the upper less strictly

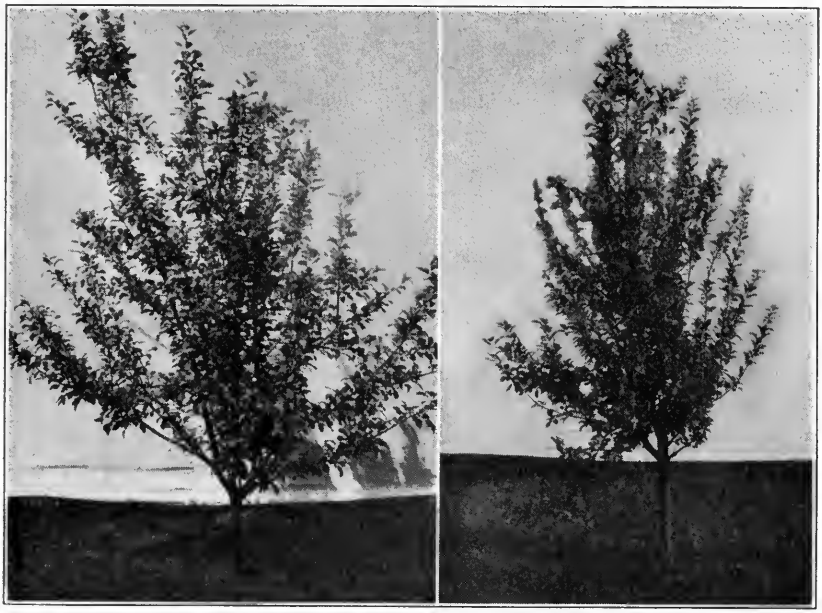

FIG. 34.—SPREADING TYPE OF *M. dioica*, JULY 11. FIG. 35.—MORE UPRIGHT FORM, JULY 11

Trees of this species are of slow growth and dwarfish habit, as indicated by the average height of 9 feet at ten years from graft.

erect than branches of the other trees. Bark of trunk rough, dark brown, on young branches and twigs a lighter brown with a tinge of green. Lenticels numerous; on the larger branches transversely elongated, on smaller branches nearly round. There are numerous spurs ½ to 1 inch in length which project at right angles from the branches. Buds large, thickly covered with white tomentum and perfectly free, pointing obliquely upward. That the trees are of slow growth and dwarfish habit is indicated by the average height of 9 feet at ten years from graft. The least upright and most spreading of these trees is shown in Fig. 34, the more upright form in Fig. 35. Other trees have been propagated and grown in orchard, but none are now living; all have been killed by blight, to which disease this form has proved to be

especially susceptible. The only representatives of the form now in the collection are two on Doucin stocks grown in the greenhouse. These were grafted in February, 1910; they are now fourteen years old, healthy, but of very slow growth.

Leaves.—Two to 4 inches long by 1 to 1½ inches wide, elliptical or some of the smaller ovate, or occasionally lanceolate, acute, crenate, slightly pubescent on both sides when young, becoming glabrous above

FIG. 36.—BUD CLUSTER OF *M. dioica*, MARCH 16, WITH FLOWERS NEARLY OPEN

The interval between the first open flower and the last of the cluster is usually three or four days.

and nearly so below, dark green; petioles slender, ¾ to 1 inch long, pubescent, broadly and deeply channelled.

Flowers.—Borne in clusters, mostly from terminal buds of short spurs. Of 77 clusters recorded, 42 had 6 flowers each, 4 had 7 each, 1 had 8, and 1 had only 4. In some cases the bud axis elongates somewhat, separating the flowers so that they appear racemose, but in others the cluster is compact, appearing umbellate; pedicels 10 mm. long, stout, pubescent. In unopened buds the calyx lobes are connivent, giving a pointed appearance to the apex of the bud. When fully open the calyx lobes are horizontal and the flower expands 10 to 12 mm. from tip to tip of the lobes; the lobes are 5 in number, narrowly triangular, acuminate with attenuated point, densely tomentose on

both sides, grayish-green with tips tinged pink, rather thick and rigid. In place of normal petals are 5 small bracts closely resembling the calyx lobes except that they are smaller and obtusely pointed; they alternate with the calyx lobes and are thickly covered with white tomentum. Stamens wanting, not even rudiments can be detected. Styles variable in number; of 11 flowers examined there was 1 each with 7, 8, 10, 12, and 15; 2 with 11 each, and 4 with 14 each; they vary in length from 7 to 10 mm. and in most flowers are more or less contorted; in the flower having 15 styles, 10 appeared normal and were bent but little, the other 5 were more slender and much contorted. The outer styles are connate at base in groups of 2 or 3 and are sparingly pubescent for about one-fourth the length; the inner styles are distinct and glabrous. Stigmas are mostly rounded capitate, sometimes oval and usually slightly two-lobed. At anthesis most stigmas glisten with exudation. Flowers of individual clusters do not open simultaneously, commonly the interval between the first open flower and the last of the cluster is three or four days. A bud cluster with 2 flowers nearly open is shown in Fig. 36.

Fruit.—The root-grafted trees in orchard produced a few flower clusters in 1915, but no fruit matured; in 1916 the amount of bloom was considerably increased, but altho 166 flowers were hand pollinated no fruit persisted to maturity. Two trees in pots from scions top-worked on Doucin stocks February 12, 1910, produced 3 fruits in 1914, 3 in 1915, and 11 in 1916, following hand pollinations with pollen of various orchard varieties. These 17 fruits ranged in weight from 18 grams to 66 grams with an average of 45 grams; in longitudinal diameter from 34 to 61 mm., with an average of 48 mm.; and in transverse diameter from 35 to 55 mm. with an average of 47 mm. There was marked irregularity in numbers of carpels. Ten of the fruits had only the normal single whorl with numbers as follows: 1 had only 1, 5 had 3 each, 3 had 4 each, and 1 had 5. Each of the 7 remaining fruits had a more or less complete second whorl of carpels superposed upon the normal whorl; in these fruits the distribution of carpels was as below; 1 had 10 carpels, 5 in each whorl; 1 had 3 in the lower whorl, and 2 in the upper; 2 had 4 in the lower and 3 in the upper whorl; 2 had 3 in the lower and 1 in the upper whorl; 1 had 5 in the lower and 3 in the upper whorl. The aggregate of good seeds from the 17 fruits was 67; of these 55 were produced in carpels of normal whorls and 12 were from superposed cells. In the fruit with 5 carpels in each whorl, each carpel of the lower whorl bore 1 seed and 3 of the 5 in the upper whorl each bore 1 seed. Maximum seed production was reached by a fruit having 5 carpels, 4 of which bore 2 seeds each and the remaining carpel 1. The 3 fruits of 1915 were parthenocarpic: each had a single whorl of 3 carpels and each carpel contained 2 ovules, but no seeds developed.

The accompanying fruit description is from fruits of cross No. 9703. The flowers were pollinated with Oldenburg pollen February 26 and the mature fruits were picked and described June 2, 1916. Two of the 4 fruits were photographed and are shown in Fig. 37. The fruit on

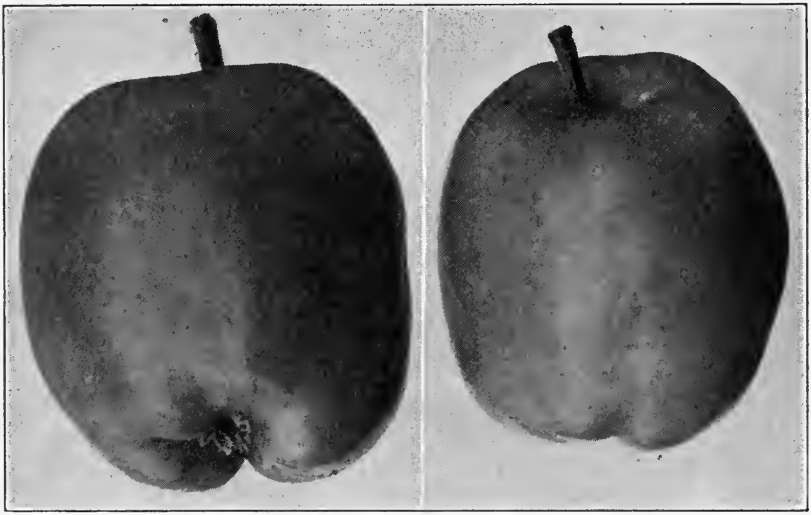

FIG. 37.—FRUITS OF CROSS NUMBER 9703, *M. dioica* x OLDENBURG

The flowers were pollinated February 26; the fruit picked June 2. This fruit is oblong in shape and dull yellow in color, with a few small, greenish dots.

the left weighed 57 grams, calipered 51 mm. in vertical diameter and 50 mm. in transverse diameter; its companion weighed 47 grams and the diameters were 49 and 45 mm.

Form oblong, irregular at both base and apex, transverse section irregular, ribbed, sides unequal, dull yellow in color, skin smooth, tender, thin, somewhat unctuous, scantily covered with a waxy white bloom; dots few, small, regular, round, greenish, inconspicuous. Cavity shallow, moderately wide, acute, irregular; stem medium in length, slender, green, pubescent. Calyx of medium size, pubescent, open. Basin medium in depth, rather broad, irregular, deeply ridged. Calyx lobes small, short, broad, acuminate, reflexed and somewhat separated at base. Calyx tube of medium size, short, cylindrical in form. Core of medium size, elliptical, median, half open. Carpels obcordate, emarginate, tufted, moderately concave. Seeds plump, rather small, dark brown. Flesh white or with a slight yellowish tinge, tender, rather dry, mildly subacid, quality only fair. The fruit at left of figure had 4 carpels in the normal whorl which bore 4 seeds and 3 carpels in a superposed whorl each of which bore 1 seed. The fruit at the right

had 5 carpels in the lower whorl which bore 3 seeds and 3 carpels in the upper whorl which bore 2 seeds.

Fruits that do not have the superposed whorl of carpels are of roundish form and much less irregular at base and apex, otherwise

FIG. 38.—FRUITS OF CROSS NUMBER 9810, *dioica* x OLDENBURG, NATURAL SIZE, PHOTOGRAPHED JUNE 7, 1916

they are the same. A further illustration of this species is given in Fig. 38. This is cross No. 9810. There were 5 buds in the cluster, 4 of which were pollinated with Oldenburg pollen March 1, 1916. Three fruits matured, were photographed June 7, 1916, and picked for description June 16.

Trees of this species have the general appearance of upright growing varieties of the common apple with leaves rather smaller than is usual. In 1916, Grimes pollen was used on 166 flowers of *M. dioica* on trees in orchard; no fruits matured. In the years 1913 to 1921, 156 flowers on trees in greenhouse have been pollinated by pollen from nine orchard varieties and three crab forms. The crosses by Yellow Transparent, Stayman Winesap, and one of two crosses by Oldenburg failed. The ten remaining crosses were successful in varying degrees and 67 fruits matured, 252 seeds were planted, and 137 seedlings

grew. There are now in orchard seventy-five trees representing seven of these crosses in numbers from two to twenty-two, and ranging in age from three to eight years. Unless attacked by blight most of these trees should reach fruit production.

16. *Malus floribunda* Siebold (821)

This species appears to have been first mentioned by Louis Vanhoutte.[1] In his work, "Flore des Serres," three colored plates illustrate the plant in bud and flower and we are told that it was introduced from Japan by Dr. von Siebold under the name of *Malus floribunda*. The plant grew in the Vanhoutte nurseries several years without attracting attention, but in the spring, presumably of the year 1864, it flowered so abundantly as to demonstrate its value as an ornamental. It was described, illustrated, and since then has received many favorable notices in various journals. It was brought from Japan as a cultivated plant and it is doubtful if it is known in the wild state. It has been largely propagated by seeds and hence numerous forms have appeared; it has also hybridized with other species and some of the hybrid seedlings have been named and disseminated by nurseries.

This species is represented in the collection as No. 821, and the trees were grown from scions received from the Arnold Arboretum in 1908. At the Arboretum the species has been grown for many years and is represented by both yellow- and red-fruited forms. Scions received here were from the typical yellow-fruited form and our trees appear identical with those at the Arboretum. The general form is low and wide-spreading with a strong tendency to the production of long wand-like branches, which in growing take a more or less upright position, but later become nearly horizontal. In the autumn of 1923 one of the two root-grafts made in 1908 measured 17 feet high, 21 feet in spread, and 9.0 inches in trunk diameter at the ground surface. Bark of trunk and larger branches very dark brownish-black; of twigs bright reddish-brown. Lenticels few, small, inconspicuous. These trees began flowering in 1912 and bloomed the last week in April each year until 1920, when the first flower opened May 7. In the spring of 1921, the first bloom came April 7; in 1922, April 17; in 1923, May 4. May 2 was the date for first bloom in 1924. A tree top-worked on Grimes in March, 1912, has formed a low, round, spreading top in all respects similar to the root-grafted trees; this flowered in 1915, again in 1916, and abundantly in 1917. The species has proved satisfactory on Doucin stocks in pots; scions inserted February 12, 1912, flowered under glass March 1, 1914, February 22, 1915, and February 26, 1916, and each season bore fruit. One of the root-grafted trees as it appeared when photographed September 24, 1915, is shown in Fig. 39.

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[1]Vanhoutte, Louis. Flore des Serres 15. 1862-1865.

Leaves.—Young leaves from mixed buds are various in form, the majority lanceolate, some elliptical or ovate or even obovate, but generally tending toward long narrow forms. Petioles short, pubescent, margins serrate or crenate, acuminate, lower surfaces finely tomentose, above nearly glabrous. Mature leaves of non-flowering shoots 2 to 3½ inches long, ovate or oblong, acute, sharply but somewhat irregularly serrate, glabrous thruout; petioles ½ inch long, stout, narrowly and

FIG. 39.—ROOT-GRAFTED TREE OF *M. floribunda,* AS PHOTOGRAPHED SEPTEMBER 24, 1915

deeply channelled. Leaf texture somewhat stiff, dark green. Detailed examination of 100 leaves, 50 from young wood and 50 from older branches, gave an average length of 3½ inches and width a little more than 1 inch; petioles averaged 1 inch in length; 58 percent of the leaves were acute, 40 percent acuminate, and 2 percent obtuse; margins were crenate-serrate in three-fourths of the leaves and serrate in the balance. None of the leaves were lobed.

Flowers.—Produced from mixed buds, terminal and lateral along terminal shoots. These shoots are commonly 2 or 3 feet in length or longer; on the two- and three-year old wood, at intervals of about ¾

inch are very short spurs, each of which produces, from the terminal bud, from 5 to 8 small leaves and flowers, in numbers as determined from count of 541 clusters, ranging from 3 to 11 with the average a little above 6. There are also numerous spurs, 3 to 6 inches in length,

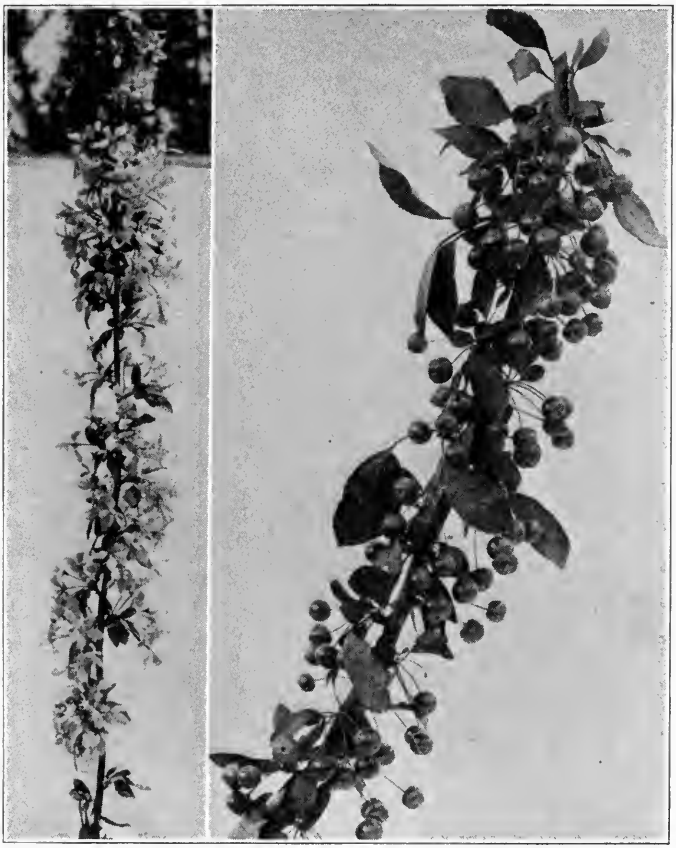

FIG. 40.—SHOOT OF *M. floribunda* IN FLOWER, APRIL 29. FIG. 41.—BRANCH IN FRUIT PHOTOGRAPHED SEPTEMBER 16

This species is chiefly valued for its beauty in flower. It propagates readily either on standard or dwarf stocks and, with little trouble, can be used freely for ornamental planting.

from interior and larger branches, the terminal buds of which produce leaves and flowers as do the buds on terminal shoots. The attractiveness of the tree at blooming time, however, centers in the long shoots because of the massing of color. Within a length of 14 inches on one shoot were 26 flower clusters opening 160 flowers, literally a mass of bloom. Young buds are of an attractive deep red, but fade to pink

before anthesis; just before opening they attain a length of 7 mm. and a breadth of 5 mm. Fully open flowers expand about 1 inch and are then light pink or in some cases nearly white. Pedicels are about an inch in length, slender, green, pubescent. Calyx lobes 5, lanceolate, erect in bud, acute, slightly pubescent outside, and densely pubescent within and on the margins. Petals oblong or elliptical, 9 mm. long by 4 mm. wide, claw very short. The range in number of stamens is from 18 to 30, the average is about 21, filaments slender, about 5 mm. long, anthers plump, light yellow. Styles 3 to 5; of 44 flowers examined 5 had 3 each, 23 had 4 each, and 16 had 5 each; they vary in length from 5 to 8 mm., connate one-third the length and hairy from base to point of separation. A portion of a flowering branch photographed April 29, 1915, is shown in Fig. 40.

Fruit.—Very small, round, or slightly oblate, somewhat conical, and flattened at the apex. Averaged from 100 fruits the weight is found to be .87 gram, longitudinal diameter 11 mm., and transverse diameter 12 mm. Color light orange-yellow with brownish blush on side exposed to sun; bloom scanty or none, skin thin, rather tough, smooth, polished; cavity shallow, broad, regular; stem rather long, 20 to 25 mm., slender, erect, usually red, glabrous; basin shallow, medium in width, obtuse, irregular. Calyx lobes uniformly deciduous; the russet scar left by the lobes small and slightly depressed below the surface; core large in proportion to the size of the fruit, round, closed. Carpels roundish, emarginate, glabrous, moderately concave. Flesh yellowish, firm, rather dry, acid. Ranges low in seed production; of 100 fruits 3 had 5 seeds each, 29 had 4 each, 26 had 3 each, 28 had 2 each, and 14 had 1 each. The average is 2.79 or approximately one for every 3⅓ ovules present. A branch in fruit photographed September 16, 1915, is shown in Fig. 41.

M. floribunda is certainly attractive when in flower; less can be said of its beauty in the fall because of the dull color of the fruit. It is chiefly valued for its spring beauty and as it propagates readily either on standard or dwarf stocks it can be, with little trouble, added to any collection or used freely for ornamental planting.

17. *Malus fusca* (841)

Schneider, C. K. Illus. Handb. Laubholzh. 1, 723. 1906.
Pyrus rivularis Douglas ex. Hooker Fl. Bor. Amer. 1, 203. 1839.
Malus rivularis Roemer Syn. Mon. 3, 215. 1847.

The Oregon crab-apple of the Pacific coast ranges from northern California to Alaska. Scions received from the U. S. Department of Agriculture under the number 19668, January, 1907. Attempts to propagate by both root- and top-grafting failed. A second lot of scions received from the Arnold Arboretum January, 1908, was propagated by both root- and top-grafting as number 841. The species is now

represented in the collection by one tree root-grafted January 20, 1908, and one top-worked on Virginia Crab on April 7, 1908. Also by two trees root-grafted in 1914. The root-grafted trees are healthy, but decidedly dwarf, advancing year by year by very small increments. The graft of 1908 now sixteen years old stands 8 feet in height, has a spread

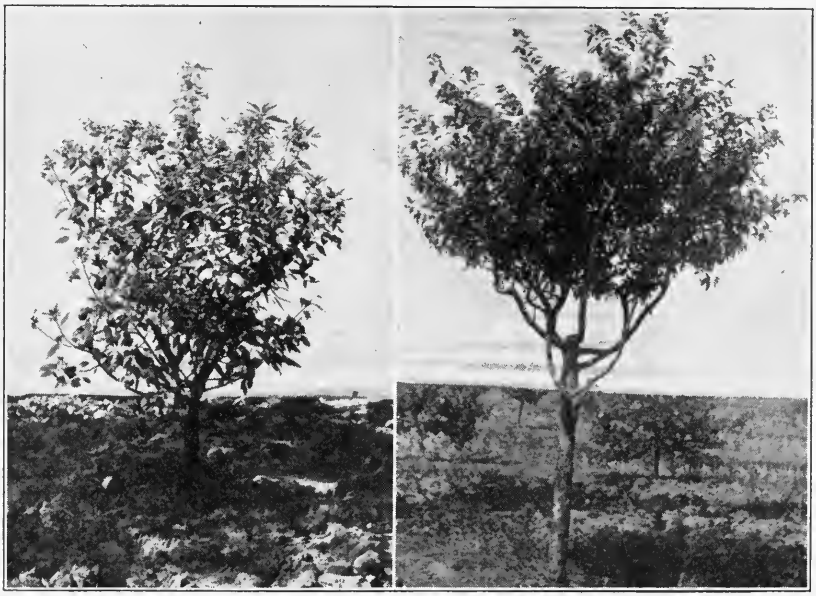

FIG. 42.—ROOT-GRAFTED TREE OF *M. fusca*, AS IT APPEARED WHEN NINE YEARS OLD.
FIG. 43.—TOP-WORKED TREE OF *M. fusca* ON VIRGINIA CRAB, AT THE SAME AGE

The root-grafted trees of this species are healthy, but decidedly dwarf, making very small gains each year. Flowering is very irregular, and later than on any other form of Malus in the collection.

of 5 feet, and a trunk diameter of 2½ inches. It produced a few bud clusters in 1914, but they fell without opening flowers and the tree has not flowered since. Appearance of the tree when nine years old is shown in Fig. 42.

The tree on Virginia Crab has produced numerous small branches which have made a very thick rounded top; as measured in the fall of 1923 it was 14 feet high, had a spread of 10 feet, and a trunk diameter of 5 inches. This tree as photographed in October, 1916, when nine years old, is shown in Fig. 43. A few flowers were produced in 1915 and greater numbers in the two following years; then for four years it did not flower; in each of the years 1921 and 1922 it flowered sparingly, but not at all in the last two seasons. Flowering appears to be very irregular and when flowers are produced they open later than

those of any other form of Malus in the collection. Bark of trunk and branches dark grayish-brown; of twigs reddish-brown, pubescent. The habit of growth is ascending.

Leaves.—Rather small and of various forms; on flowering shoots they are ovate, obovate, oblong, orbicular or even narrowly lanceolate, mostly sharply serrate, acute or acuminate, or sometimes variously incised and occasionally three-lobed, pubescent below, sparsely villous above. Leaves produced later on new non-flowering shoots vary in outline from ovate to lanceolate, but the greater portion approximate the ovate form, 1½ to 3½ inches long, ¾ to 1½ inches broad. Some leaves are obtusely rounded to the petiole, others have a slight taper; mostly three-lobed, the small lateral lobes above the middle; often the large central lobe is incised in such manner as to appear three-lobed. Margins serrate or sometimes crenate-dentate below and serrate towards the apex, acuminate, becoming glabrous above and nearly so below. Petioles ½ to 1 inch long, slender, pubescent when young, becoming glabrous. Stipules small, linear, in part persistent. In spring and early summer the leaves are thin and delicate in texture, later they become somewhat coriaceous.

Flowers.—Borne from terminal buds and to some extent from upper lateral buds of terminal shoots and from terminal buds of numerous short spurs. The number of buds to the cluster ranges much higher than for other species; 30 clusters examined have distribution as follows: 2 had 7 buds each, 5 had 10 buds each, 5 had 11 each, 13 had 12 each, 3 had 13 each, and 2 had 14 buds each. Buds small, globular, greenish-white or sometimes faintly tinged with pink, the axis is short and the buds appear umbellate. Pedicels slender, 18 to 22 mm. long, each with from 1 to 3 linear, brown bracts, usually on the basal half, slightly pubescent, as is also the ovary. Calyx lobes obtusely triangular, acute, pubescent outside, more densely so inside, deciduous. Flower expands 13 mm., petals white, 5 to 7 mm. long, 3 to 5 mm. wide, oval or nearly rotund, rounded at apex, claw very short; stamens 16 to 20, filaments slender, 3 to 5 mm. long, anthers large, plump, creamy white; pollen grains large, elliptical, almost white; styles 3 or 4, slender, 4 mm. long, connate half the length, glabrous, tips compressed, stigmas oval, elliptical. The flowers are fragrant and suggest Philadelphus.

Fruit.—Oblong, regular at base and apex, small; 34 fruits averaged give the individual weight as .46 gram, vertical diameter 9.7 mm., transverse diameter 9 mm. Color depends upon degree of maturity. Until the first of October all are green. Fruits gathered October 25 were nearly all yellow, some having a light red blush and a few were partially colored a darker brownish-red, none were "dark purple, almost black" as described by Nuttall. Skin smooth, thin, tough; no dots apparent; cavity shallow, broad, obtuse, regular; stem slender, 20

to 22 mm. long, erect, green, glabrous; basin shallow, broad, obtuse, irregular, ribbed; core small, oblate, distant, closed; carpels elliptical, entire, mucronate, glabrous, varying in number from 3 to 5; of the 34 fruits dissected, 23 had 3 carpels each, 10 had 4 each, and 1 had 5. Seeds plump, of medium size, light brown; the average of seeds to each

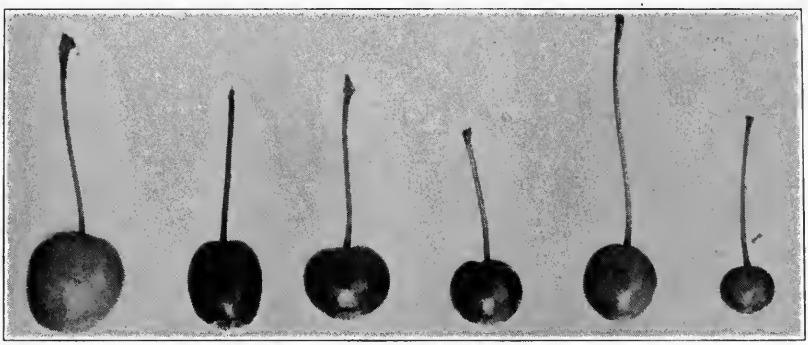

FIG. 44.—SOME SMALL-FRUITED CRABS, NATURAL SIZE

Left to right: *M. arnoldiana* (802), *M. fusca* (841), *M. floribunda* (821), *M. sargenti* (843), *M. atrosanguinea* (804), *M. toringo* (19664), dwarf form.

fruit as found for 34 fruits is 1.3; this is the lowest average of any of the crab group examined. Flesh white, moderately juicy, acid. A single fruit photographed natural size may be seen the second from the left in Fig. 44.

18. *Malus dawsoniana* Rehder. Sargent, C. S. Trees and Shrubs 2, 23. 1913.

Scions of this crab were received from the Arnold Arboretum as *Malus rivularis* var. in 1908, and again in 1912, both root-grafts, and top-grafts were made, and it is now represented in the collection by three trees top-worked on Doucin stocks, grown in pots in the greenhouse; one grafted in 1910, the others in 1914. In the orchards are four trees, one top-worked on Grimes in 1912 and three from root-grafts made the same year. The trees in orchard are of remarkably vigorous growth, forming very dense, symmetrical crowns. Branches are ascending becoming somewhat spreading. Production of a very great number of short interior branches seems characteristic of the species; these branches account for the observed density and it is from their terminal buds that most of the flowers are borne. Bark of trunk and larger branches very dark, rough, and scaly. Shoots of the current year are, at first, dull green, but become light brown before the close of the season.

Leaves.—Those of terminal shoots elliptical, oval, or ovate, 2 to 5 inches long, ¾ to 2¼ inches wide, acute, irregularly crenate or crenate-serrate, glabrous above, scantily pubescent below. Petioles ¾ to 1¼ inches long, pubescent. Leaves from spurs and short interior branches small and of various forms. Flowers from terminal buds of short, mostly interior, branches, usually 5 or 6 in each cluster; buds deep pink fading to white as petals open, apex rounded.

Flowers.—Expand 35 mm., calyx lobes narrowly triangular 5 mm. long, acuminate, pubescent, becoming reflexed; petals oval or obovate, apex round, 18 mm. long, 10 mm. wide, pure white, claw short, slender; stamens 20, filaments slender, 9 mm. long, anthers plump of medium size, light yellow, styles 5, slender, 8 mm. long, connate for 3 mm. from base, glabrous at base, a few hairs about the point of separation, stigmas small, oval, capitate, ovary pubescent, tinged red; pedicels stout, 12 to 15 mm. long, pubescent.

Fruit.—Oblong or obovate-oblong. For 20 fruits weights range from 12 to 18 grams with an average of 16 grams, average vertical diameter is 32 mm., average transverse diameter 24 mm. Green or yellowish-green, sometimes with a light red blush, bloom rather heavy, waxy, white; skin smooth, tough, thin; dots few, regular or irregular, russet, conspicuous; cavity shallow, narrow, obtuse, regular; stem slender, erect, glabrous, 11 to 21 mm. in length. Calyx small, open or closed, pubescent; basin shallow, broad, or often with no depression; calyx lobes long, slender, accuminate, erect or reflexed, mostly persistent; an occasional fruit is found with calyx lobes regularly deciduous; calyx tube long, funnel-form; core small, elliptical, median, closed; carpels obovate, emarginate, tufted, slightly concave; seeds plump, medium size, light brown; flesh yellowish, firm, crisp, juicy, sharply subacid. Only one attempt to breed this crab has been made. In 1918 using Jonathan as the pollen parent 69 flowers were pollinated, but no fruits developed.

19. *Malus halliana* (823) Koehne. Gatt. Pomac., 27. 1890.

This is another of the species of Malus from Japanese gardens introduced by Dr. von Siebold. It does not seem to be known in the wild state; some have thought that it came originally from China and have associated it with the Chinese *Malus spectabilis.* The affinities of the species, however, appear to be with either *Malus baccata* or *Malus toringo* rather than with *spectabilis,* and there is no definite record of the plant back of its existence in Japanese gardens. It has appeared under various trade names as *Pyrus malus floribunda, Pyrus baccata parkmani,* and *Pyrus toringo parkmani.* The most complete description is given by Dr. Alfred Rehder in Sargent's "Trees and Shrubs."[1]

[1]Sargent, C. S. Trees and Shrubs 1, 35. 1905.

This species is represented in the Station collection as No. 823, by two trees grown from root-grafts on apple seedling stocks, made in January, 1908. These trees have supplied scions for further propagation. Three trees grafted in February, 1912, are now in orchard on the Douglas tract and 12 trees grafted in January, 1914, were planted in the south orchard in the spring of 1915. The trees first propagated and now sixteen years from the grafts are still small and shrubby; the two trees average 7 feet 9 inches in height, 9 feet 3 inches in spread, and the average trunk diameter is 2.7 inches. Bark of trunk dark grayish-brown, branches are of the same color but lighter in shade; twigs reddish-brown, more or less whitened with scarf skin and scantily pubescent.

Leaves.—Mostly ovate varying to elliptical or some of the smaller lanceolate, 1¼ to 3¼ inches long, ½ to 1¼ inches wide, acute or acuminate, obtusely serrate to nearly entire, glabrous both sides, except that when young there are some long hairs along the glandular midrib above; these soon disappear; upper surface dark shining green, below lighter. Petiole short, ⅜ to ½ inch in length, at first pubescent, but soon becoming glabrous; deep red or purple, the color extending up the prominent midrib and gradually diminishing towards the apex. Texture thick, leathery. The small ovate or lanceolate serrate stipules mostly persistent. Late in the fall many leaves become more or less purple.

Flowers.—Flowering began in 1915 with the production of a few clusters. In 1916 the number was considerably increased; all thus far borne are from terminal buds of shoots or spurs. Of 30 clusters examined one had 3 flowers, 5 had 5 flowers each, 17 had 6 each, and 7 had 7 each. Flowers expand 1 inch. Pedicels slender, 30 to 32 mm. long, glabrous, dark purplish. Ovary glabrous, dark red; calyx lobes 5, oblong, truncate, about 2 mm. long, glabrous outside, pubescent with white wool on margin and inside, dark purplish-red. Petals varying in number from 10 to 13, ovate or sometimes obovate about 13 mm. long by 9 mm. wide tapering rather abruptly to the slender claw which is 1 to 2 mm. long. Buds deep reddish-pink; as the petals expand they show various shades of pink, but when fully open are of uniform light rose-pink. Stamens 25 to 35, filaments slender, 5 to 10 mm. long; anthers plump, light yellow. In most clusters the central flower is staminate, occasionally 2 staminate flowers are found in a cluster and on the other hand all flowers of some clusters are hermaphrodite. Most flowers have from 2 to 4 petaloid stamens. Styles 2 to 5, mostly 5, about 12 mm. long, purple, connate for a length of 2 mm. or about one-sixth the total length, hairy with thick matted wool from base to above the point of separation or about half the length of the styles; stigmas yellow, small, oval, oblique. Altho flowers were numerous on both trees in the spring of 1916 neither tree matured any fruit. On one

tree 106 flowers in 30 clusters were emasculated and, on May 5, hand pollinated by Oldenburg, but neither these nor the flowers left open to insect visitors developed fruit. In later years flowers were pollinated by Yellow Transparent, Jonathan, and Domine, but in no case did fruits mature. The trees, however, have borne fruits, presumably from insect pollination.

Fruit.—The average of fruits weighed is 0.45 gram; vertical diameter 8 mm., transverse diameter 9 mm.; oblate, regular at base and apex, sides equal; ground color green, over-color purplish-red, skin smooth, tough, thin, dots none, no cavity and no depression at the truncate apex, calyx lobes deciduous, stem slender, 33 to 38 mm. long, red, glabrous; core large, round, median, closed; carpels roundish, entire, glabrous, deeply concave; flesh greenish, firm, juicy, acid. The delicate appearance of the foliage at flowering time, the varying shades of pink in the flower, and the distinctness with which each flower cluster stands out are features that combine to enhance the beauty of this shrub.

20. *Malus ioensis* (825) (Wood) Britton and Brown. Illus. Fl. 2, 235. 1897.

Pyrus coronaria var. *ioensis* Wood Class Book, 333. 1860.
Pyrus ioensis Bailey. Amer. Gard. 12, 473. 1891.

The native wild crab of Illinois and adjacent states. Scions received from the Arnold Arboretum in January, 1908, and propagated as No. 825. Ten root-grafts on ordinary apple seedling stocks were made January 17, 1908; three grew; two lived to be planted in orchard April 30, 1910; one of these was vigorous from the beginning and still survives; the other was weak at time of planting and died the second year in orchard. The one living tree, now sixteen years old, is symmetrical, round-topped, somewhat spreading; height 19 feet 2 inches, spread 19 feet 5 inches; trunk diameter 6.6 inches. The bark of trunk and branches is dark grayish-brown, young twigs reddish-brown thickly covered with gray pubescence. Thorn-like spurs are numerous.

Leaves.—Three to 5 inches long, 1 to 2½ inches wide, ovate, oblong, or elliptical in outline, tapering below to the stout, pubescent petiole which is from 1 to 1½ inches in length; variously dentate, notched or lobed, acute or often obtuse; pubescent below, and when young, with scattered hairs above. At maturity glabrous above and nearly free from pubescence below except along the midrib and veins.

Stipules small, linear, in general caducous, but occasionally persisting and falling with the leaves. After frosts the leaves become yellow, or dark red, or purplish, falling earlier than do those of orchard varieties of apples.

Flowers.—The first flowers were borne in 1913, five years from the graft; the amount of bloom has increased each year since. Flower clusters are single, terminating short twigs and spurs. The inflorescence is cymose and the bases of the pedicels are more or less vertically separated, suggesting a raceme. The number of flowers in a cluster ranges from 3 to 6. Of 50 clusters 2 had 3 flowers each, 18 had 4 each, 27 had 5 each and 3 had 6 each. Buds are globular, deep pink; as flowers open the petals fade somewhat, but remain pink. Pedicels rather stout, 31 to 37 mm. long, pubescent. Ovary pubescent; calyx lobes 5, triangular, slender, acuminate, pubescent both sides. Flowers expand 45 mm. Petals 24 mm. long by 13 mm. broad, oval or elliptical, emarginate, tapering below to the slender claw which is 4 to 5 mm. long. The long claw so separates the 5 petals that the flower has a very open appearance. Stamens 20, filaments slender, 10 to 13 mm. long; anthers light yellow, becoming reddish-brown after dehiscence. Styles 5, slender, 13 mm. long, tinged with red, connate one-third the length and hairy from base to above the point of separation; stigmas capitate, oval. Because of the elongation of the bud axis the clusters are very open; there is no crowding, each flower is distinct, free from its neighbors.

Fruit.—Round, irregular at base, and somewhat ribbed at apex, green, scantily covered with waxy, gray bloom; weight and dimensions as averaged from 100 fruits from the tree described are as follows; weight 13.04 grams, longitudinal diameter 27 mm., transverse diameter 30 mm. A further lot of 212 fruits obtained from a wild roadside tree, near Olney, Richland county, gave the following averages: weight 7.12 grams, longitudinal diameter 22 mm., transverse diameter 25 mm. Averages for the aggregate of fruits are, weight 9 grams; longitudinal diameter 23 mm.; transverse diameter 26 mm. Fruit from the wild tree was distinctly smaller than that from the tree in orchard. This may be a varietal difference or with equal probability a difference due to environment, one tree being under culture, the other in an undisturbed fence row. A further difference in the two lots of fruits is seen in seed production. The average of good seeds for the wild fruits is 3.86; for the tree under cultivation 4.89.

Skin smooth, unctuous, tough, thin; dots many, small, round, dark gray, inconspicuous; cavity of medium depth, rather broad, acute; stem long, about 34 mm., slender, somewhat clavate, erect, green, pubescent; base of the stem often thickened and corrugated; basin medium in depth to deep, rather broad, acute, irregular, ribbed. Calyx lobes small, rather long and slender, acute, fleshy at base, erect, inflexed; the tips finally wither away leaving the apex of the fruit crowned with the browned, dead styles, which persist from the apex with the protruding "pistil point." This "pistil point" is enlarged and of pyramidal form; it is projected thru and nearly fills the calyx tube,

so that this tube, instead of contracting to a point at its base, is broadest at base and tapers towards the apex. This construction is peculiar and has not been encountered in any other species of Malus. The core is of medium size, round, median, closed; core lines clasping; they are hard, bony, forming a conspicuous division between core and outer flesh. The normal carpels are 5 and in addition there are 5 rudimentary carpels alternating with the others, not appearing as cells, but as

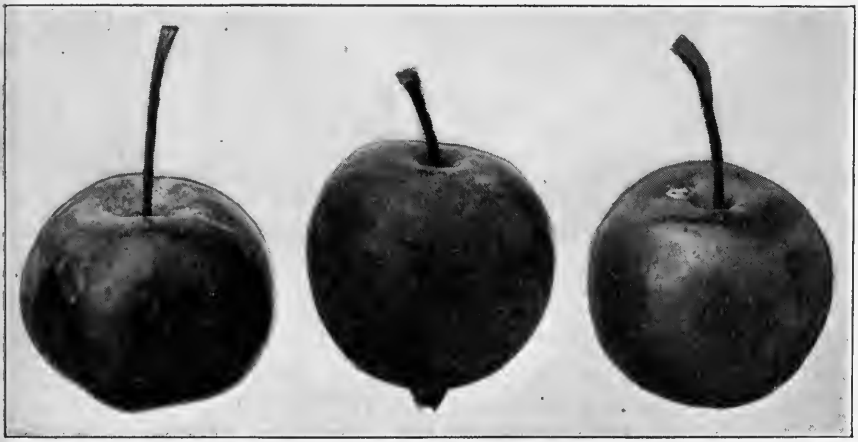

FIG. 45.—FRUITS OF THREE OF THE CRAB FORMS, NATURAL SIZE

Left to right: Yellow Siberian Crab (857), *M. sylvestris fastigiata bifera* (820), *M. ioensis* (825).

more or less straight lines of hard bony tissue. The 5 carpels forming cells are roundish, deeply concave when seeds have developed, and only slightly so when the ovules are abortive. Seeds are large, plump, and of dark red color. The flesh is yellowish, firm, crisp, juicy outside, the core lines dry and mealy within, very acid. A single fruit may be seen at the right in Fig. 45. *M. ioensis* has been used as the female parent in six crosses with six orchard varieties as pollen parents and all of these crosses were reasonably successful in fruit production. The total of pollinations was 469 and 181 fruits matured; 1,049 seeds were planted, an average of 5.79 seeds from each fruit. Approximately 45 percent of the seeds germinated, but the seedlings were so deficient in vitality that one-fourth of them died before time to plant in nursery; others died each year until in the fall of 1923 only 20 of 469 seedlings were living and 65 percent of these graded as "poor" and will not survive another year. The five best trees may survive to fruiting, but this is doubtful.

The experience with *M. ioensis* as a mother plant gives no encouragement to its use in breeding.

21. *Malus ioensis fl.pl.* (826)

Scions received January 9, 1908, were, in part, worked as root-grafts on ordinary apple seedlings on January 20 and, in part, stored and then on April 6 inserted as top-grafts on a young tree of Fameuse. Some of the top-worked scions made a feeble start, but all died before the end of the first season. Five of the root-grafts grew thru the season, were stored in a pit for the winter, and again planted in nursery in the spring of 1909. Four trees survived in the spring of 1910, and were planted permanently in orchard. Growth during the early years was slow; in later years more rapid. The trees have formed rounded, spreading, symmetrical crowns with numerous branches pushing obliquely upward. The largest tree measured in the fall of 1923 was 16 feet 4 inches high, had a spread of 15½ feet and a trunk diameter of 5.5 inches. The trees flowered sparingly for the first time in 1913; each year since the amount of bloom has increased until now it is abundant. Flowers are borne singly or in clusters of 3 to 5. In clusters the axis is elongated and the inflorescence racemose. Buds just before opening are bright pink, globular, ½ inch or more in diameter. Fully open flowers expand from 2¼ to 2¾ inches; pedicels are stout, heavily pubescent, bracteate, 40 to 45 mm. in length. Calyx lobes 5, triangular, acuminate, 8 mm. long, densely pubescent both sides, tips slightly reflexed in fully open flowers. Petals large, 32 mm. long by 24 mm. wide, oval, somewhat abruptly contracted to the long claw, margin usually more or less waved, varying in number from 18 to 28, with the average for 14 flowers examined, 23; stamens range in number from 25 to 34 with an average of 30, filaments slender, the outer 19 mm. long, the inner successively somewhat shorter; anthers large, plump, orange-yellow. Petaloid stamens occur in most flowers in all degrees of modification. Styles 18 mm. long, slender, reddish in color, varying in number from 9 to 11, free to the base, pubescent one-third the length. Stigmas irregularly oval.

When not in flower these trees are indistinguishable from those of *M. ioensis* (825). No fruits have been produced. Ten flowers on a tree on dwarf stock in the green house were hand-pollinated in the spring of 1915 with Yellow Transparent pollen, but no fruit development followed. Pollen of this form of Malus was used on 4 flowers of Yellow Transparent, but without result. Evidently the floral modifications are such as to preclude the use of this plant in breeding. This full flowered form of *M. ioensis* was introduced 25 or more years ago by E. A. Bechtel's Sons of the Staunton Nursery at Staunton, Macoupin county, as Bechtel's Double-Flowered American Crab. It is said to have originated near Staunton. The plant deserves a place in any collection of ornamentals for the beauty of its flowers and particularly of the large, bright pink buds.

22. Malus, Fluke Apple, Mercer County Crab, Fluke Wild Crab (822)

Scions received from the Arnold Arboretum in January, 1908. Several root-grafts made January 11 were planted in nursery May 7; most of these started growth but all died before the end of the first season. April 6, 1908, several scions, reserved for the purpose, were top-worked on a Sops of Wine tree that was then four years old; these scions grew, forming a round, somewhat spreading top. This tree was removed to another orchard in February, 1913; it bloomed in 1914, but died in the fall of that year from blight which attacked the trunk. In 1910 scions from the top-worked tree were grafted on a potted paradise stock. This tree is still living and, tho small, it flowered in each of the years 1913, 1914, 1916, and 1917; in each of the two earlier years hybrid fruits were matured, in 1916 the pollinations all failed, and in 1917 only 1 fruit matured. Again in 1912 scions from the top-grafted tree were used in root-grafting and seven of the trees grown are now in orchard on the Douglas tract as trees 15 to 21 in Row 36.

Bark of larger branches is reddish-brown, smooth, with scattered, small, round, dull straw-colored lenticels; twigs dark reddish-brown, pubescent when young, becoming glabrous except at the nodes.

Leaves.—Larger leaves ovate or occasionally oblong, 2½ to 4 inches long, 1 to 1½ inches wide, truncate at base, obtuse or shortly acute, coarsely and irregularly crenate-dentate, in some cases slightly lobed, persistently pubescent below, becoming glabrous above; there are also some small leaves nearly orbicular in form and irregularly bluntly serrate. Petioles ½ to 1 inch long, stout, pubescent. Stipules minute, linear, more or less persistent. Flowering from terminal and upper lateral buds of shoots and terminal buds of short spurs. Of 15 clusters examined, 8 had 5 buds each, 6 had 4 each, and 1 had 7. Buds globular, becoming obovate as they approach anthesis, dark pink fading to light pink as flowers open. Pedicels rather short and stout, bracteate, densely pubescent.

Flowers.—Flower expands 30 to 35 mm. Calyx lobes 5, rather broadly triangular, acute, densely pubescent on both sides, closely appressed in bud, becoming acutely reflexed in open flowers. Petals 5, obovate, about 15 mm. long and 9 mm. wide, light pink; claw short and broad. Stamens 16 to 20, filaments slender, 7 mm. long, anthers large, plump, dark golden-yellow. Styles 5, slender, 11 to 12 mm. in length, free to the base or very nearly so, hairy from base up for 4 mm. In fully open flowers the styles have a characteristic red color. Stigmas round or somewhat irregular, often slightly two-lobed; when young dark garnet, fading to the same shade of red that distinguishes the style. Fig. 46 is a twig in bud as photographed in the greenhouse March 19, 1913.

Fruit.—Oblate, base regular, apex slightly irregular, cross-section somewhat ribbed, sides equal, color yellow, a moderate amount of waxy white bloom; skin smooth, thin, tough; a few russet and many white, small, round dots, the russet dots are conspicuous, the white inconspicuous. Cavity shallow to medium in depth, acute, slightly ridged, and in some fruits lipped. Stem medium in length, about 14 mm., slender, erect, green, pubescent. Basin varies from shallow to deep, broad, obtuse, slightly ribbed. Calyx medium to small, pubescent, closed or half open; core small, obcordate, median, closed; stamens median, core lines clasping; carpels obovate, emarginate, somewhat tufted, moderately concave. Seeds plump, of medium size, dark brown. Flesh yellowish, firm, rather dry and somewhat astringent, subacid; quality poor.

FIG. 46.—TWIG OF MERCER COUNTY CRAB IN BUD

Photographed in the greenhouse March 19. In flowers that are fully open the styles have a characteristic red color.

The 4 fruits of 1913 developed from flowers pollinated with Yellow Transparent pollen March 21 were fully mature and ripe when picked and described September 18. The single fruit of 1914 developed from a flower pollinated with Grimes pollen March 24, was picked and described as mature August 22. This fruit was photographed July 23, 1914, as it hung on the twig, and appears in Fig. 47. The average of the 5 fruits is a fruit weighing 54 grams, a vertical diameter of 40 mm., and a transverse diameter of 51 mm. The average seed production is 3.4, which is somewhat below the average for the crab group.

The tree from which the scions used by the Station were taken was received at the Arnold Arboretum, as a graft, March 2, 1902, from the Experiment Station at Brookings, South Dakota, as the "Fluke Apple." In response to an inquiry regarding this crab Professor Hansen of the South Dakota Station replies as follows,

"What the Arnold Arboretum received from us is evidently the Mercer or Fluke Wild Crab itself. The late N. K. Fluke of Davenport found this growing wild in Mercer county, Illinois. I have been raising it ever since. See tracing at the end of this letter which is a print from a specimen raised at this station in my fruit breeding work. Early in December, 1911, I visited Mercer county and traced it to the pasture where the tree was found wild near Sherrard, Illinois, but the tree had been cleared off some years previously. I also regret that this crab apple was not named after Mr. Fluke himself since Downing describes the Mercer apple of southern origin so that the name Mercer is really occupied. It may not be too late yet to name this wild crab the Fluke."

The diagram referred to by Professor Hansen accords perfectly with diagrams of fruits grown at the Illinois Station, and the crab now growing as No. 822 in the Illinois series doubtless has descended by graft from the original wild crab which Mr. Fluke called the Mercer County Crab and which, as suggested by Professor Hansen, may with propriety be called the Fluke Apple.

FIG. 47.—FRUIT OF MERCER COUNTY CRAB, AS PHOTOGRAPHED JULY 23
This crab is of the Soulard type.

Further testimony regarding the origin of this crab is found in a paper read before the Iowa State Horticultural Society by Mr. N. K. Fluke[1] in 1900. Mr. Fluke speaks of his apple work as follows:

"Ten years ago, having trees in bloom of the Mercer County Crab, which is, no doubt, a natural variation of the Soulard type, and by no means a hybrid of *Pyrus Malus,* because it was a large tree and was found growing in a crab thicket far removed from any cultivated fruit, I pollenized its blossoms with pollen of Ben Davis, Duchess, Jonathan, and Maiden Blush. Number 27 (from above work) fruited last year, is yellow in color, about like medium-sized Maiden Blush; season the first of September; a fairly good eating apple."

[1]Fluke, N. K. Notes on the new fruits. Rpt. Iowa State Hort. Soc. 1900.

Craig and Hume[1] describe the Mercer County Crab as follows:

"The fruit spurs are decidedly like those of Malus and thorns do not occur. . . . Irregularities in leaf characteristics, vigorous growth, diminution of reproductiveness, all indicative of hybridity, are present, and we give it as our opinion that this crab is the result of a cross of *Malus* and *Iowensis*. The seeds average 3.1 to the apple. . . . This crab originated in Mercer county, Illinois, and was introduced by N. K. Fluke of Davenport, Iowa."

Experience regarding the breeding qualities of this crab is too limited to warrant an opinion as to its possibilities, as the only pollinations have been upon the one dwarf tree in the greenhouse. With this one individual the results have not been such as to arouse enthusiasm. In 1913, 11 flowers pollinated by Yellow Transparent gave 4 fruits which contained 14 seeds, 9 of which germinated; only one weak tree survived, made a feeble growth in the two following years, and then died. The following year 9 flowers pollinated by Grimes gave 1 fruit containing 3 seeds, one of which germinated, but the seedling died the first season. In 1916, the 34 pollinations made by Grimes, Jonathan, and Akin all failed; for the next year 23 flowers pollinated by Fanny matured 1 fruit containing 3 seeds, none of which germinated. Again in 1918, Yellow Transparent pollen was used on 4 flowers, but no fruits matured. The net result, then, from 81 pollinations in the five years is entire failure. This is not an encouraging record. When pollinations can be made on a more extensive scale it is hoped better results may be attained. In 1914 pollen of the Fluke apple was used in 23 pollinations on *M. ringo;* 11 fruits matured, 25 seeds were planted, 13 germinated, and 2 seedlings now in their tenth year are in orchard; one of these is 8 feet 10 inches high, has a spread of 7 feet 5 inches, a trunk diameter of 3.1 inches, and is graded as "good." The other is 3½ feet high, spreads 2 feet 3 inches, has a trunk diameter of .7 inch, and is graded as "poor." These are the only hybrids in which the Fluke apple appears as one of the parents.

23. *Malus malus* 441/1 (829)

The scions were received from the Arnold Arboretum in January, 1908, and were taken from a tree grown at the Arnold Arboretum from seed received from Bavaria in 1889 under the name *Pyrus Malus L.* From an examination of herbarium specimens it is scarcely possible to distinguish it from *Malus pumila* of Europe or from certain forms of *Malus sylvestris.* Three trees were planted in orchard in 1910 from root-grafts made January 18, 1908. These trees have grown rather slowly. They are symmetrical and in the first years very erect; in later years they have become somewhat spreading. As measured in

[1]Craig and Hume. Native crab apples and their cultivated varieties. Iowa Acad. Sci. 7, 139. 1899.

1923 the height was 14 feet 2 inches, spread 15 feet 9 inches, and trunk diameter 5.6 inches. The trunks are 2 feet long with smooth, dark olive-brown bark; above, the branches are numerous and the foliage dense.

Leaves.—Ovate or oblong 2 to 5 inches long; 1 to 2¼ inches wide, coarsely and irregularly dentate or toward the apex serrate, acute or obtuse, glabrous above, pubescent along midrib and veins below. Petioles stout, ¾ to 1½ inches long, pubescent. In general appearance the trees are strikingly like small trees of the common apple. In 1911 scions from one of the trees were worked on paradise stocks growing in pots; these dwarfs have been forced under glass each spring since. The species was also top-worked on a Grimes in 1912 and has formed a round symmetrical top.

In the spring of 1917, 2 flower clusters were borne by the top-worked tree and from one of these the following flower description was made. Cluster of 6 buds terminal on a 4-inch spur. Leaves from the mixed bud ovate to oblong, 1 to 2 inches long and ½ to ⅞ inch wide, crenate-serrate, acute, pubescent along the veins above, lower surface covered with a fine, close pubescence. Petioles ½ inch long, pubescent. Buds umbellate, opening nearly together, pink. Pedicels stout, 15 mm. long, pubescent, tinged brown, bracteate; ovary pubescent, green or in part brownish. Calyx lobes 5, triangular acuminate, 7 mm. long, 3½ mm. wide at base, pubescent both sides.

Flowers.—Expand 40 mm. Petals oval, 17 mm. long by 14 mm. wide, with short claw; fading to nearly white, but many retain small light pink spots outside. Stamens 20, filaments slender, 5 to 9 mm. long; anthers plump, light creamy yellow. Styles 5, slender, flattened at tips, 10 mm. in length, connate for 2 mm. up from base, glabrous at base; a few short hairs about the point of separation; stigmas irregularly oval.

In the spring of 1918, on one of the dwarfs in greenhouse, 5 flowers were pollinated by Delicious; 1 fruit containing 9 seeds matured; 7 of the seeds germinated and five seedlings now in their sixth year are in orchard. These seedlings are much alike, they average 5 feet high, 4 feet 3 inches in spread, and 1 inch in diameter.

Fruit.—Description of the 1 fruit from this cross is as follows: Weight 88.7 gms., vertical diameter 54 mm., transverse diameter 63 mm.; oblate-roundish, base irregular, apex irregular, slightly conical, cross-section irregular, ribbed, sides equal; size medium; ground color green, faintly striped and the surface mostly covered with dull light red, bloom medium, waxy, white; skin smooth, tough, of medium thickness; dots many, small, round, white, inconspicuous; cavity medium in depth and width, acute, regular; stem 40 mm. in length, slender, erect, green, pubescent; calyx small, pubescent, closed. Basin

deep, acuminate, irregular, ribbed; calyx lobes small, long-slender, acuminate, reflexed, calyx tube conical, of medium size; core medium, cordate, median, closed, cells axile, uniform; carpels ovate, emarginate, tufted, concave; flesh yellowish, tender, dry, mealy, subacid, quality poor, flat, and without distinctive flavor.

24. *Malus malus* var. (830)

Number 830 is represented by three trees which are now in their tenth year from root-grafts made with scions from the Arnold Arboretum in January, 1908, one tree on paradise in pot from scion inserted in February, 1910, and four trees from root-grafts made in 1914. The dwarf tree flowered and fruited in 1914; the older trees in orchard in 1916. Trees erect, dwarfish in habit, branches numerous, producing many short blunt spurs. The older trees are now 10 feet high with a spread of 8 feet and an average trunk diameter of 2.4 inches.

Leaves.—Large, thick, leathery, 3 to 5 inches long, 1 to 2½ inches wide, ovate or oblong or some of the smaller lanceolate, acute or acuminate, crenate-dentate, glabrous thruout. Petioles stout, medium in length to short.

Flowers.—Produced from terminal buds of spurs and from sessile lateral buds. Young buds globular, deep red, becoming oblong and light pink. Open flowers are nearly pure white, only slight tinges of pink remaining, expanding 35 mm. Pedicels slender, 30 mm. long, glabrous, bracteate. Calyx lobes 5, narrowly triangular, acuminate, glabrous outside, pubescent inside. Petals large, ovate to oblong, rounded at apex, 18 mm. long, 13 mm. wide, claw 2 mm. in length. Stamens usually 20; the numbers as counted for 26 flowers were as follows; 18 flowers had 20 each, 3 had 19 each, 2 had 18 each, 2 had 17 each, and 1 had 16; filaments slender, 5 to 8 mm. long, anthers plump, light yellow, pollen abundant, dark orange at time of dehiscence. Styles 5, slender, 8 mm. long, connate one-third length, glabrous immediately at base, then hairy to just above the point of separation; stigmas oval, oblique.

Leaves are somewhat in advance of flowers so that the trees are very leafy when the flowers open. The light green of the leaves and the nearly white blossoms on long pedicels present a handsome appearance. Fig. 48 from photograph of a terminal twig taken in the greenhouse February 24, 1917, shows the relative development of leaves and flower buds from a terminal mixed bud.

Fruit.—Roundish, slightly oblate, quite uniform in shape, but not in size. Of 41 fruits the minimum weight is 5.15 grams, the maximum 31.15 grams with an average of 16.77 grams. Vertical diameters range between 18 and 34 mm., with an average of 27 mm.; transverse diam-

eters range between 22 and 42 mm., with an average of 33 mm. Ground color yellow overlaid with red which varies from light to medium in shade, skin smooth, thin, tough; dots few, large, white, inconspicuous. Calyx lobes deciduous in all fruits; core medium size cordate, median, closed; cells axile; carpels roundish, obovate, entire, glabrous; flesh yellowish, firm, rather dry, acid. In general appearance of tree and foliage this form resembles *M. pumila* or a dwarf form

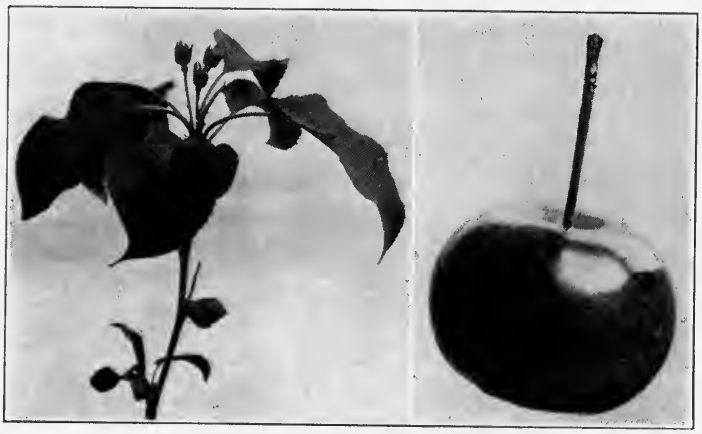

FIG. 48.—TWIG OF *M. malus* VAR. (830) SHOWING RELATIVE DEVELOPMENT OF LEAVES AND FLOWER BUDS. FIG. 49.—MATURE FRUIT PHOTOGRAPHED SEPTEMBER 11, NATURAL SIZE

Leaves are somewhat in advance of flowers in this species, so that the trees are very leafy when the flowers open. The leaves are light green and the blossoms, which are almost white, are on long pedicels.

of *M. sylvestris*, but the long slender pedicels and the regularly deciduous calyx suggest the *baccata* group. It is probable that this variety is a hybrid between one of the many forms of *M. malus* and some form of *M. baccata*. Fig. 49 shows a single fruit natural size, as developed from a flower, on an orchard tree, pollinated by Ben Davis May 8 and photographed at maturity September 11, 1916. In Fig. 50 is shown a cluster of fruits natural size, developed under the cross number of 11428 from flowers on a dwarf tree in the greenhouse pollinated February 28; picked, described, and photographed July 10, 1917. This form of Malus has been used as the female parent in six crosses. The cross by Domine failed; those by Ben Davis, Yellow Transparent, Yellow Siberian Crab (857), *M. prunifolia* var. (19651), and *M. niedwietzkyana* (834) were successful in percentages varying from 1 to nearly 90. These crosses are represented in orchard by 165

seedlings from 3 to 7 years old. As a male parent it has been used in 5 crosses. On flowers of Yellow Siberian Crab (857) no fruits developed; on *M. malus* var. (19667) and *M. prunifolia xanthocarpa,* there were 4 fruits in each cross, but seeds failed to germinate; only two crosses are represented in orchard, one on *M. prunifolia* var. (19651)

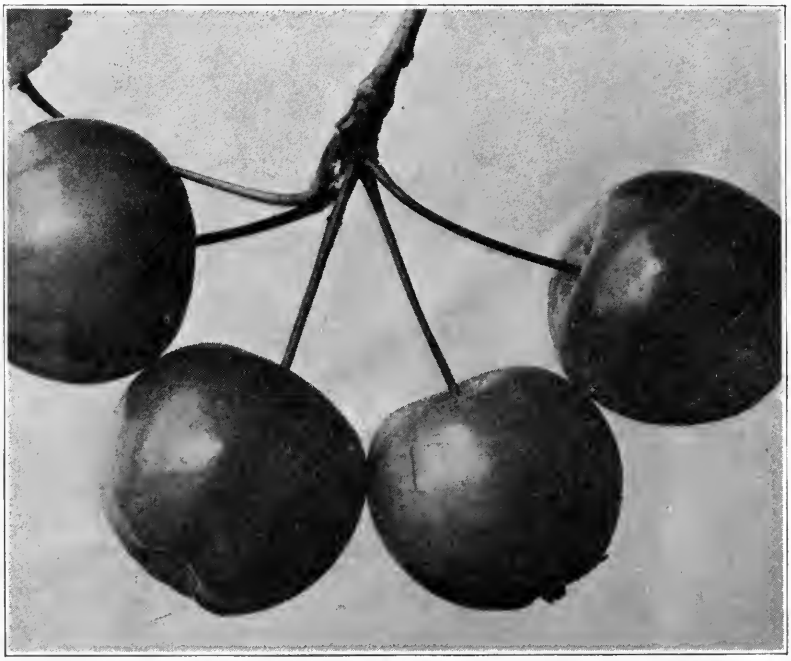

FIG. 50.—CLUSTER OF FRUITS OF *M. Malus* VAR. (830), NATURAL SIZE

Developed from flowers on dwarf tree in the green house pollinated by *M. niedwietzkyana* February 28, 1917; picked and photographed July 10, 1917. Seventeen fruits were matured from 19 pollinations.

by ten seedlings and the other on *M. baccata oblonga* by nineteen seedlings; the seedlings vary in age from seven to ten years.

25. *Malus malus* var. (19667)

Scions from Arnold Arboretum received in January, 1907, thru the U. S. Department of Agriculture under the number of 19667 and carried in the Station collection as one of the 19000 series under the same number. At present represented by one tree from root-graft, on ordinary apple stock, made March 23, 1907, and now seventeen years old, six trees from root-grafts, on apple stocks made February 29, 1912, and now in orchard on the Douglas tract, one tree top-worked on

a Higby Sweet March 18, 1912, three trees on paradise stocks grafted March 5, 1913, and forced each year since under glass, and four trees from root-grafts made January 22, 1914, and now in orchard on the south tract.

FIG. 51.—TREE OF *M. malus* VAR. (19667) FROM ROOT-GRAFT MADE MARCH 23, 1907, AS IT APPEARED OCTOBER 2, 1915

This tree is spreading in habit, and straggling branches make the general outline of the crown irregular. The bark of the smooth trunk is greenish-brown, the branches dark olive-green, and the twigs reddish-brown.

Habit of growth is best shown in the root-graft of 1907. This tree is now 17 years from graft, 14 feet 6 inches high, has a spread of 12 feet 10 inches, and a trunk diameter of 5.2 inches. Its habit is spreading, some branches are straggling, and the general outline of the crown irregular. Bark of the smooth trunk is greenish-brown, branches dark

olive-green and twigs reddish-brown. This tree as it appeared when photographed October 2, 1915, is shown in Fig. 51.

Leaves.—Those on flowering shoots are orbicular, oblong, obovate or sometimes lanceolate, 1 to 3½ inches long, acute, sharply serrate; on non-flowering shoots elliptical, oval, or oblong, 4 to 5 inches long and 2 to 2¼ inches wide, acute or acuminate, coarsely doubly-dentate. All are pubescent below and are more or less covered with scattered hairs above when young; later they are glabrous above. Petioles pubescent, those from mixed buds are long and slender, from lateral buds of non-flowering shoots shorter and much more robust.

Flowers.—A few clusters of flowers from terminal buds of short interior spurs were produced in 1913; in succeeding years the amount of bloom has increased and comes both from terminal buds of short spurs and from terminal and lateral buds of shoots of the preceding year. The internodes of terminal shoots are rather long, separating the bud clusters so that they do not appear crowded; the flowering portion of shoots varies from 3 or 4 to 8 or 10 inches long. Flowers and leaves come together, but the pedicels are so long that the flowers are conspicuous. There is wider range in number of flowers to the cluster than is found in other forms; the 138 clusters counted gave distribution as follows:

With 3 buds each	4
With 4 buds each	3
With 5 buds each	8
With 6 buds each	39
With 7 buds each	55
With 8 buds each	21
With 9 buds each	6
With 10 buds each	2

Young buds are globular and very deep red, they become elongated as petals increase in size and the color fades to shades of pink; fully open flowers retain but a trace of the pink color. Flowers expand 23 to 28 mm. Pedicels slender, pubescent, 40 to 57 mm. long in upper clusters, 30 to 40 mm. long in lower, smaller clusters, ovaries pubescent. Calyx lobes 5, triangular, acute, about 3 mm. long, pubescent both sides, erect in bud, tips becoming reflexed in open flowers. Petals 5, oval to oblong, rounded at apex, tapering to a very short claw, 20 mm. long, 15 mm. wide. Stamens, as determined from examination of 75 buds, vary in number from 17 to 31 with an average a little above 23; filaments slender, 6 to 9 mm. long, white; anthers plump, light yellow. Styles 5, or occasionally 6, slender, 7 mm. long, connate ⅓ the length and hairy from base to above the point of separation. Stigmas oval, capitate.

Fruit.—Round or slightly oblate, base regular, apex somewhat ribbed, cross-section sometimes obscurely ribbed, sides often somewhat unequal. Weight and dimensions have been determined for two dis-

tinct lots of the fruits of this form of Malus. A lot of 221 fruits developed from flowers open to pollination by insects and from which the following averages were obtained: weight 5.92 grams, longitudinal diameter 19 mm., transverse diameter 21 mm., and number of seeds to each fruit 3.77. A further lot of 215 fruits developed from protected hand-pollinated flowers gave exactly the same average diameters, but the average weight is 4.9 grams and the average number of seeds 4.10. It is not held, however, that the difference in manner of pollination is accountable for the decreased weight or the increased seed production in the lot from hand-pollinated flowers. Were the results here shown similar for other groups of other forms of Malus it might be assumed that manner of pollination was the direct cause of the differences, but results are not in the least uniform; they vary greatly and in both directions. Probably the differences appearing are not greater than might reasonably be expected from entirely distinct lots. It is an interesting coincidence, however, that the diameters of the two lots are identical, and this adds stability to the averages for these dimensions. The ground color of the fruit of this form is a clear yellow, the over color bright, light to medium red; bloom scant, waxy, gray; skin smooth, polished, thin, tough. Cavity medium in depth, rather broad, regular, rounded. Stem very long, slender, clavate, erect, green, pubescent. Calyx deciduous in most fruits; of 248 fruits examined 201, or 81 percent, had deciduous calyx lobes, while for 47, or 19 percent, the lobes were persistent; basin shallow, rather broad, obtuse, irregularly ribbed; core of medium size, oblate, median, closed; carpels roundish, emarginate, glabrous, moderately concave. Seeds are plump, above medium in size, long-pointed, rather dark brown; flesh yellowish, firm, juicy, very acid. A fruiting twig as photographed Sep-

FIG. 52.—FRUITING BRANCH OF *M. malus* VAR. (19667)

The ground color of this fruit is a clear yellow, with the over-color a bright red. In tree characters this form of Malus resembles *M. sylvestris,* but the fruit characters are those of the *baccata* group.

FIG. 53.—FRUIT CLUSTER OF *M. malus* VAR. (19667)

This single cluster is from one of the dwarf trees in pots; the flowers were pollinated with Oldenburg pollen on March 28, 1914, and the photograph of the fruit was taken July 30 of the same year.

tember 15, 1915, is shown in Fig. 52 and a single cluster in Fig. 53. This single cluster is from one of the dwarf trees in pots; flowers of the cluster were pollinated with Oldenburg pollen on March 28 and photograph of the fruit was taken July 30, 1914. See also a single fruit of this form of Malus below at the right in Fig. 54. In tree characters this

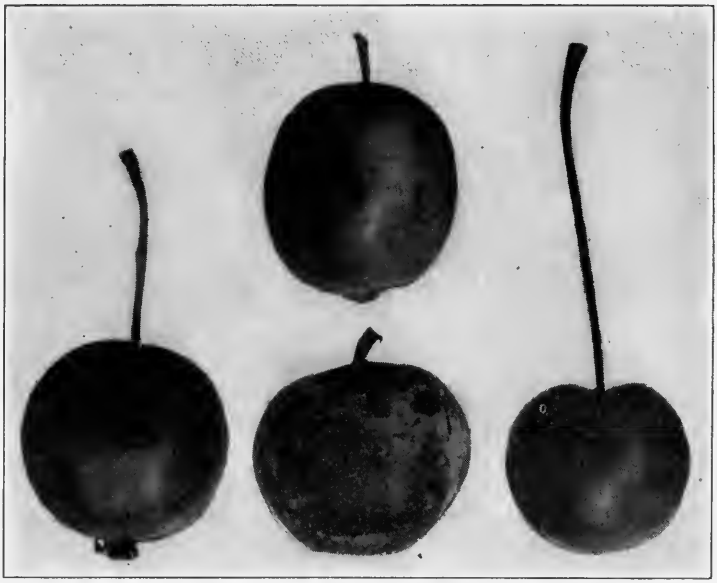

FIG. 54.—FRUITS OF FOUR OF THE CRAB FORMS OF MALUS

Above: *M. ringo sublobata* (19689). Below, left to right: *M. prunifolia* var. (19651), *M. microcarpa* (19644), *M. malus* var. (19667).

form of Malus resembles *M. sylvestris,* but the fruit characters are those of the *baccata* group. It is quite probable that it is a hybrid between a form of *sylvestris* and a form of *baccata* or it may be a combination of *M. prunifolia* and *M. baccata.*

The tree has merit as an ornamental altho it does not present such dense masses of flowers as characterize some other forms. The fruit is handsome and commonly persists until late in October. It propagates readily, is adapted to forcing, and controlled pollination of flowers has been exceptionally successful.

M. malus var. (19667) has served as female in 23 crosses by 9 orchard varieties and 4 crab forms. Three of the crosses produced no fruits, 3 bore fruits with seeds, but the seeds failed to germinate, 1 germinated one seed but the seedling did not live. Of the others 3 were by Yellow Transparent with 53 as the aggregate of pollina-

tions, maturing 30 fruits and now represented by 65 trees in orchard, 8 to 10 years old. Oldenburg pollen was used in 4 crosses with 194 pollinations yielding 78 fruits, and these crosses are represented in orchard by 168 seedlings. Jonathan pollen was used in 2 crosses with 219 pollinations maturing 47 fruits and represented in orchard by 110 seedlings. The remaining pollen parents and the number of seedlings representing each cross are as follows: Maiden Blush 2; Domine 2; Grimes 5; Oliver 13; Sops of Wine 80; Sweet Bough 109.

The aggregate of pollinations in the 23 crosses was 948; number of fruits matured 307, giving 32.88 percent as the degree of success. This is based simply on fruits matured and takes no account of seedless fruits, or fruits whose seeds did not germinate, or of fruits producing seedlings too weak to live. Similar success percentage for the aggregate of all crosses made is approximately 24 percent; hence the percentage of success given for the group of crosses in which the Malus under consideration served as the female parent may be considered as sufficiently high to rate the plant as a good breeder. Use as the pollen parent was much less successful; 10 crosses were made on six varieties and the Soulard Crab, 7 failed and the other 3 were not highly successful; 2 crosses on Oldenburg with 17 pollinations, matured 3 fruits, and 1 cross on Grimes with 50 pollinations yielded 17 fruits. For the 10 crosses there were 140 pollinations maturing 20 fruits, indicating 14.28 percent as the success percentage, a very low rate of success. Apparently this form of Malus is more successful as a pistillate parent than as a pollen parent.

26. *Malus malus* var. *pendula* (832, 19688)

Represented in the collection under the number 19688 as root-grafted trees from scions received in 1907 from the Department of Agriculture; and also under number 832 as both root-grafted and top-grafted trees from scions from the Arnold Arboretum in 1908. All trees have a decidedly pendulous habit; the top-grafts have grown with a fair degree of vigor; root-grafts grew slowly during the first three or four years, but later exhibited a degree of vigor equalling the top-grafts. Branches of the root-grafted trees trail close to or directly on the ground; a tree eleven years from the graft had dimensions as follows: extreme height 3 feet 10 inches, greatest spread, 10 feet 10 inches, and trunk diameter 3.2 inches. This tree as photographed July 11, 1916, is shown in Fig. 55. The drooping habit precludes root-grafting as a method of propagation; the form is only adapted to high top-working. The habit of a tree, top-worked in March, 1908, is shown in Fig. 56 as photographed October 26, 1911. This drooping form commends itself only as a curiosity; it has no economic value. Bark light gray with a tinge of olive-green; twigs reddish-brown, but appearing light gray, because of the dense, close pubescence.

Leaves.—Coarse, dark green, 3½ to 5½ inches long, 1 to 2 inches wide, coarsely crenate-dentate, acuminate, densely tomentose below, becoming glabrous above; petioles short, stout, covered with a dense persistent tomentum. Stipules small, linear or lanceolate, petioled, mostly persistent.

Flowers.—From terminal buds of twigs of the preceding year, in clusters of 6. Buds light pink fading to white as flowers open. Flowers

FIG. 55.—TREE OF *M. malus pendula* (832) IN ITS NINTH YEAR FROM ROOT-GRAFT

All trees of this variety show a decided tendency to droop; branches of the root-grafted trees trail close to or directly on the ground. Obviously this form is only adapted to high top-working as a method of propagation.

expand 45 mm. Calyx lobes 5, broadly triangular, acute, 7 mm. long, 3 mm. wide at base, densely tomentose on both sides, reflexed in open flowers. Petals 5, oval in form, 20 mm. long, 14 mm. wide with claw 2 mm. in length. Stamens range in number from 15 to 22 with an average of 18, filaments slender, 4 to 8 mm. long, anthers plump, light yellow. Styles 4 or 5, slender, 8 to 11 mm. long, connate one-third length and densely hairy from base to above the point of separation; stigmas oval, oblique.

Fruit.—Round or slightly oblate, more or less irregular at base and apex and in cross-section somewhat ribbed, sides unequal, size medium; as averaged from 3 fruits the weight is 122 grams, longitudinal diameter 60 mm. and transverse diameter 68 mm. The ground color is green, blushed and irregularly striped with medium red which

in spots becomes quite dark, covered with a waxy bloom which has a purplish tinge; skin smooth, of medium thickness, tough, dots many, irregular, or round, white, conspicuous. Cavity of medium depth, medium in width, acute, regular; stem short, 8 to 10 mm. long, slender, clavate, erect, green, pubescent. Calyx of medium size, pubescent, closed; basin medium in depth and breadth, acute, irregular, ribbed; calyx tube of medium size, conical. Core cordate, of medium size, median, closed or sometimes half open; stamens median, core lines clasping; carpels elliptical or obovate, entire, tufted, moderately concave. Seeds plump, of medium size, dark colored; flesh white, firm, crisp, juicy, subacid, of good flavor. Season late September. Two fruits somewhat below average size, but photographed natural size, are shown in Fig. 57.

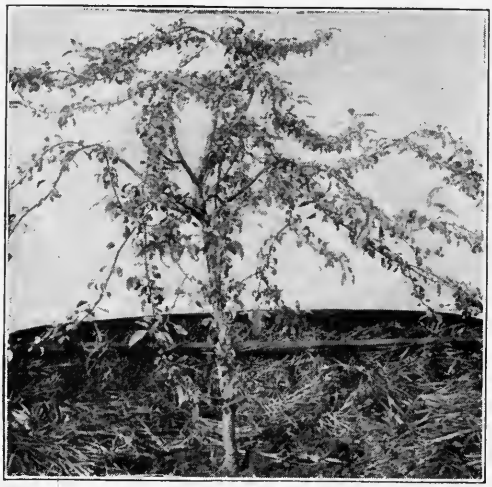

FIG. 56.—TOP-WORKED TREE OF *M. malus pendula* (832) THREE YEARS FROM INSERTION OF THE SCIONS

The drooping form of this species, even when top-worked, makes it of no value except as a curiosity.

27. *Malus microcarpa* (19644)

Scions from the Arnold Arboretum were received thru U. S. Department of Agriculture in January, 1907, and root- and top-grafts were made under the accession number 19644, which is retained for plants in the Station collection. There is a tree from graft on Doucin in 1910 that has flowered under glass each year since 1913. A twig from this dwarf tree, in bud as photographed March 12, 1913, appears in Fig. 58, and Fig. 59 shows the appearance of the top-worked tree in October, 1916, five years from insertion of the scions. When young *M. microcarpa* is strictly erect in habit with numerous branches which all grow straight up. As the tree gets older the branches become ascending and by the twelfth year they are distinctly spreading.

A tree top-worked in 1912 now measures 14 feet 5 inches in height, 18 feet 6 inches in spread, and 6.2 inches in diameter of trunk.

FIG. 57.—FRUITS OF *M. malus pendula* (832), NATURAL SIZE

These two fruits, which are somewhat under the average size, were photographed August 17, 1916. The apple is green in color, with irregular stripings of medium red, and it is of a good flavor.

A root-graft of 1907 lacks 2 inches of being 18 feet high, is 19 feet 4 inches in spread, and 6.7 inches in diameter of trunk.

Bark of the trunk dark brown, branches olive-green and twigs reddish-brown. Shoots of the season are still somewhat pubescent at the tips in October. Lenticels are few and inconspicuous. Habit of

FIG. 58.—TWIG OF TREE OF *M. microcarpa* (19644) IN BUD ON DWARF STOCK IN GREENHOUSE, AS PHOTOGRAPHED MARCH 12, 1913

In this species, a large proportion of the flowers are borne from terminal buds of short spurs, but there are also small masses of flowers appearing from terminal and lateral buds of terminal shoots.

growth, especially as regards trend of branches and tendency to production of short spurs, is shown in Fig. 60, from photograph taken during the dormant season of a tree seven years old from root-graft.

Leaves.—Variable in size; on lower and interior shoots they are from 1 to 3½ inches long, ovate or lanceolate; on rampant terminal shoots they range from 3 to 4½ inches in length, are broadly ovate or nearly orbicular, acute, irregularly crenate-dentate; glabrous above and sparingly pubescent below. Petioles ½ to 1¼ inches in length, stout, pubescent. Stipules which are long persistent on some leaves are small, lanceolate, petioled.

Flowers.—A graft of 1912 began flowering in 1916, and with the exception of 1917 has bloomed each year since. The earliest date for full bloom was April 15 in 1921, while May 10 in 1920 was the latest date. May 1 is the mean date for an average of eight years. A large

proportion of the flowers are borne from terminal buds of short spurs, but there are also small masses from terminal and lateral buds of terminal shoots. Most flower clusters have 6 buds each, a few have 5 or 7, and one had a single bud. Bud clusters are compact and show considerable differences in advancement, terminal clusters start earlier

FIG. 59.—TOP-WORKED TREE OF *M. microcarpa* (19644) FIVE YEARS FROM GRAFTING

The tree of this species is strictly erect in habit when young, the branches all growing straight up. By the time the tree is twelve years old, however, the branches are distinctly spreading.

and advance more rapidly than do those from lateral buds. The flower expands 25 mm. Calyx lobes narrowly triangular, acuminate, pubescent both sides, petals in unopened buds dull pink, becoming white as the flower opens, obovate to oblong, rounded at apex, rather abruptly contracted to the very short claw. Stamens vary in number from 17 to 21, filaments slender, varying in length from 4 to 10 mm., anthers plump, light yellow. Styles 5 in most flowers, but those having 3 or 4 are not rare, 8 to 10 mm. long, connate ⅓ the length and slightly hairy from base to middle, stigmas sometimes capitate, sometimes oval, oblique.

Fruit.—The fruit is round or slightly oblate; 312 fruits weighed and measured gave an average weight of 7.32 grams, a vertical diameter of 21 mm., and a transverse diameter of 25 mm. The seed average is 5.8, which is above the average for fruits of the crab group. Base and apex are regular, ground color yellow blushed light

FIG. 60.—TREE OF *M. microcarpa* (19644) SEVEN YEARS FROM ROOT-GRAFT, SHOWING TREND OF BRANCHES AND NUMEROUS SHORT SPURS

red indistinctly striped with dark red. Bloom moderately heavy, waxy, purple; skin smooth, thin, tough; dots few, irregular, areolar, russet, conspicuous. Cavity medium in depth, rather broad, acuminate, regular; stem short, 8 to 14 mm. long, slender, clavate, erect, russet, glabrous. Calyx lobes regularly deciduous in all fruits; 800 apples picked and examined especially with reference to this character, had all lost the lobes, leaving russet scars such as are characteristic of fruit with deciduous calyx. From examination of the description sheets of fruits resulting from crosses made, it is found that of 212 fruits, 210 had

lost the calyx in the normal way, in one the lobes were persistent, and in the remaining fruit two lobes with fleshy bases persisted, while the other three lobes were deciduous in the regular way. Basin medium in depth, broad, acute, regular. Core small, elliptical, median, closed; core lines meeting, cells axile. Carpels elliptical, entire, glabrous, mod-

FIG. 61.—FRUITING TWIG OF *M. microcarpa* (19644), NATURAL SIZE

From a dwarf tree grown in pot, and bearing fruits resulting from pollinations made March 3, 1914. Photograph taken July 30, 1914.

erately concave. Seeds plump, dark brown, of medium size. Flesh yellowish, firm, crisp, juicy, acid. A twig on dwarf tree grown in pot and bearing fruits resulting from pollinations made March 3, 1914, is shown approximately natural size in Fig. 61, from photograph taken July 30, 1914. The same tree again bearing fruit in 1916 is shown

FIG. 62.—DWARF TREE OF *M. microcarpa* (19644) IN POT

This tree, shown bearing fruit in 1916, is the same one from which the twig shown in Fig. 61 was taken.

entire in Fig. 62, from photograph taken June 21. A single fruit also appears at the center below in Fig. 54.

The affinities of this species are with *M. baccata* and it is doubtless a hybrid form of that species.

28. *Malus niedwietzkyana* Dieck.

Malus medwietzkayana Dieck. Neuheiten Offerte des Nat. arb. Zöschen, 16. 1891. Wiener. Illus. Gartenz, 164. 1891. Gard. Chron. 5, 3d. ser. 9, 461. 1891.

Malus niedwetzkayana Dieck. Neuheiten Offerte des Nat. arb. Zöschen, 18. 1892. Koehne. Deut. Dendrol., 259. 1893.

Pyrus niedwetzkayana Hemsley. Curtis's Bot. Mag. 3d ser. 60, plate 7975. 1904.

Pyrus malus Durand and Jackson. Ind. Kew. Sup. 1, 262. 1906.

This curious species is so different from any other form of Malus that it is, perhaps, worthy of consideration in some detail. The history and geographical distribution is best given by direct quotation from published accounts of the species. Dr. Dieck, who named the species, is proprietor of the National Arboretum at Zöschen, Saxony. Shortly after the appearance of his catalog of novelties which included this newly constituted species, Dr. E. Goeze gave the following account of the species.[1]

"*M. medwietzkyana*—This curious wilding has, as a wild or a cultivated plant, a wide distribution in West and Central Asia, and has apparently not yet been described. Dr. Dieck obtained it from Kashgar and the Talgar plateau in South-west Siberia, but it is probable that under the name of Kuzugjoran an identical form exists in the lesser Caucasus, and which is highly esteemed by the Swabian colonists in Trans-Caucasia. Except the old leaves, all parts of the tree are red, bark and wood, as well as flowers and fruits, which resemble small Sina-apples; even the pulp, which has a fine flavour, is of a dark rosy colour. In Kashgar the cultivated form bears the name, Kisil alma; the wild variety is to be named after President Medwietzky, who collected it with many other interesting shrubs in South-west Siberia."

[1]Goeze, E. Gard. Chron. 9, 461. 1891.

Following is the account of the species as given by W. B. Hemsley, Keeper of the Herbarium and Library, Royal Gardens, Kew.[1]

"This remarkably distinct apple is an instance in which it seems better for practical purposes to avoid the theoretical species and publish it under the single name it goes by in cultivation. It might be argued that it is only a variety of Pyrus Malus L., but we do not propose discussing that question here. It certainly is a most striking object, whether in flower or in fruit.

"As to the spelling of the distinctive name, we have adopted the one used by the author in his second account of the plant, where, however, he gives no explanation of the deviation from the first. In each case he states that he names it after his patron, who collected it wild in the Ili District, South-west Siberia. Mr. Dieck further states that this apple is widely spread in Western and Central Asia, both in a wild state and cultivated and he believes it is the same as a common wild apple of the Caucasus, which is highly prized for its fruit by the Swabian colonists. He received it from Kashgar and the Plateau of Talgar and the European stock appears to have been raised from the seed of cultivated trees in the former locality, where it is called 'Kisil alma' or red apple. With the exception of the leaves all parts of this apple are red,—bark, wood, flowers and fruit and the leaves turn red in autumn. Even the flesh of the nice-tasting fruit is of a deep rose-red.

"*Pyrus Niedzwetzkayana* is hardy at Kew where it flowered profusely last spring and is just ripening fruit at the time of writing this (Sept. 1, 1904). The fruit actually represented in the plate is from a drawing made by Mr. George Massee, of a very fine fruiting specimen sent to Kew from Bitton, in August, 1901, by Canon Ellacombe."

Continuing, Mr. Hemsley gives the following description of the plant:

"A small free-growing tree. *Flowering-branches* long, straight, stiff, rather thick: bark smooth, very dark purple. *Leaves* on long slender petioles, on the fruiting branches rather thick, stiff, nearly glabrous, tinged red, lanceolate, oblanceolate or oblong, three to five inches long without the petiole, finely crenately-toothed, shortly acuminate, slightly hairy along the midrib; petiole one to two inches long, bright red as well as the midrib, slightly hairy. *Flowers* deep rose-purple, an inch and a half to an inch and three-quarters across, very numerous, clustered at the ends of very short lateral branchlets; stalks slender, six to nine inches long. *Calyx* woolly, white; lobes lanceolate, acute, about a quarter of an inch long. *Petals* obovate. *Stamens* longer than the smooth styles. *Fruit,* pendulous, conical, one inch and three-quarters to two inches long, skin crimson-purple, flesh rose-purple throughout."—W. B. H.

The plate accompanying Mr. Hemsley's article shows a flowering branch with numerous flowers which appear lighter in color than those produced by trees in the Station collection. The fruit, said to be natural in size, measures 5 cm. in long diameter and 4.8 cm. in transverse diameter. It shows a markedly conical apex and appears to be ribbed.

Scions of *Malus niedwietzkyana* were received from the Arnold Arboretum thru the U. S. Department of Agriculture January 29, 1907,

[1]Hemsley, W. B. Curtis's Bot. Mag. 3d. ser. 60, colored plate No. 7975. 1904.

as number 19683. Both root- and top-grafts were made and most scions started growth, but all died before the end of the season. The second lot of scions direct from the Arnold Arboretum January 9, 1908, were added to the collection under the number 834. At present the species is represented by one tree, top-worked on Fameuse in 1908, which flowered for the first time in 1916; five trees propagated in 1912, and one tree on paradise stock in pot, grafted February 24, 1911, and forced each spring since. This has flowered regularly since 1914. From the experience in propagating this species it may be said that in nearly all cases the initial growth from the graft has been slow, feeble, and disappointing, but each succeeding year there has been a decided increase in vigor of growth. All trees are spreading in habit and there is some tendency to the production of long straggling branches that need to be controlled in order to preserve symmetry. Bark of trunk and main branches is very dark brownish-black with a tinge of purplish-red, twigs have much the same colors, but in somewhat lighter shades. Lenticels are numerous, small, transverse, conspicuous.

Leaves.—Mostly oblong or lanceolate, but some are ovate or even orbicular, 2½ to 4 inches long including the petiole, which is usually about 1 inch in length, acuminate, crenate-dentate, pubescent below and with scattering hairs above when young, becoming glabrous above and nearly but not entirely so below; petioles are also pubescent when young, but become entirely glabrous and assume a bright red color which extends thru the midrib and larger veins. The leaves are rather thin, but of leathery texture even when young, becoming stiff in autumn, dark green with a red or purple tinge that becomes more pronounced as the season advances; in autumn most leaves become entirely red or purplish-red. Stipules minute, linear, falling as the leaves expand.

Flowers.—The full bloom dates vary from April 20 in 1921 to May 10 in 1920. The mean date, as an average for seven years, is about May 2. The trees flower heavily every second season and seldom fail to have a few clusters. Flowering from terminal buds of shoots of preceding year and from sessile lateral buds at various points along the shoots, but principally near the apex. Of 68 clusters recorded as to number of buds, 1 had 2, 10 had 4 each, 38 had 5 each, 18 had 6 each, and 1 had 7. Buds are large, globular, becoming elongated as the petals increase in size; the color is a deep maroon which fades to aster-purple when petals are about ready to open. Flowers measured expand from 4 to 5 cm. Pedicels short, 10 to 12 mm. long, stout, pubescent, red, as is also the heavily pubescent ovary. Calyx lobes 5, broadly triangular, 4 to 5 mm. long, 3 mm. wide at base, obtuse or acute, pubescent both sides and red in color. Petals 5, reddish aster-purple, both inside and outside, oval, rounded at apex, abruptly taper-

ing to the claw which in fully open flowers is distinct, wide, and rather long. Stamens vary in number from 23 to 27, filaments 8 mm. long, rose-red, shorter than the styles; anthers plump, yellow, overspread with purple, darker in color than the filaments, pollen abundant, separating readily on dehiscence and not inclined to adhere in masses. Styles 5, slender, 12 mm. long, equal, rose-red, connate less than one-fourth the length, hairy from base to above point of separation.

FIG. 63.—BUD CLUSTER OF *M. niedwietzkyana* DIECK (834), PHOTOGRAPHED MARCH 21, 1914

The buds are a deep maroon which fades to an aster-purple when the petals are about ready to open. The trees of this species flower heavily every other season, and seldom fail to have a few clusters.

Stigmas yellow, oval or somewhat irregular, oblique, slightly prolonged down the styles. A flower cluster with one expanded flower is shown in Fig. 63.

Fruit.—Roundish-oblate with conical, somewhat irregular apex. The fruit described weighed 23.8 grams, measured 36 mm. in vertical diameter and 38 mm. in transverse diameter, and possibly had not reached full maturity when it fell from the tree. Ground color green almost completely obscured by the crimson-purple over-color; the dark purplish color is accentuated by the presence of an abundant, powdery, purple bloom; skin smooth, thin, tough; dots few, large, irregular, areolar, conspicuous. Cavity medium in depth, rather broad, acuminate, regular; stem short, stout, clavate, erect, green, pubescent; calyx of medium size, closed. Basin moderately deep, medium in breadth, acute, irregular, ribbed; calyx lobes of medium size, broad and short, obtuse; tips reflexed, bases somewhat separated. Carpels

elliptical, entire, tufted, moderately concave. Flesh tinged thruout with reddish-pink, firm, somewhat dry, subacid, and with a slightly bitter taste. As grown at this Station, the *niedwietzkyana* fruit does not have the fineness and niceness of quality which it is described as having in the Siberian Plateau, but is rather poor, having a flat taste, and lack of flavor. The fruit described (Fig. 64) developed from a flower hand pollinated with Yellow Transparent pollen March 7, 1916. It fell from the tree June 16 and was described the same day.

M. niedwietzkyana has been used quite freely in crosses altho the degree of success attained has been very low. As the female

FIG. 64.—FRUIT OF *M. niedwietzkyana* DIECK (834) FROM FLOWER POLLINATED IN GREENHOUSE BY YELLOW TRANSPARENT, MARCH 7. PHOTOGRAPHED JUNE 7, 1916

The fruit of this species grown at this Station is not of such fine quality as it is said to have in the Siberian Plateau. It is characterized by a flat taste and lack of flavor.

parent it has served in 19 crosses with pollen from 11 orchard varieties; 14 of these failed; 5, 2 by Domine, 2 by Delicious, and 1 by Yellow Transparent, matured 8 fruits. Pollinations were 10¼ percent successful for these 5, but less than 2 percent successful for the whole group of crosses. In orchard there are 28 seedlings derived from these 5 crosses. Pollen of *niedwietzkyana* has been used in 34 crosses on 17 orchard varieties and 11 crab-forms; 18 of the crosses failed and from 16 crosses there are living in orchard 253 trees at ages of 6 to 8 years. For the whole group 580 pollinations matured 87 fruits, or 15 percent of the pollinations were successful.

29. *Malus prunifolia macrocarpa* (837)

This is represented in the collection under the number 837 by one tree from root-graft made January 18, 1908; one tree from top-graft on paradise stock in pot, made February 12, 1910; one top-graft on Fameuse April 6, 1908; and several younger trees propagated in later years.

The tree from root-graft of 1908 best exhibits the characteristics of this form. It is of very erect habit, 15 feet in height with an extreme spread of 11 feet 5 inches, and a trunk diameter of 5.4 inches. Bark light brown with a tinge of olive-green; twigs are reddish-brown, glabrous except when very young, and then only sparsely pubescent.

FIG. 65.—TWIG OF *M. prunifolia macrocarpa* (837) IN BUD IN GREENHOUSE, MARCH 12

Leaves.—Ovate or oblong, or some of the smaller lanceolate, 2½ to 5 inches long, ¾ inch to 2 inches wide, acuminate, crenate-dentate, or in some cases serrate towards the apex, sparingly pubescent below when young, becoming glabrous, thick, leathery in texture. Petioles stout, ¾ to 1½ inches long, glabrous.

Flowers.—Produced from terminal and lateral buds of terminal shoots and from terminal buds of spurs. Buds small, globular, pink, fading to pure white as flowers open. Flower expands 1¼ inches. Pedicels slender, 25 mm. long, sparsely pubescent, lower part of ovary pubescent, upper part and outer surface of calyx lobes glabrous. Calyx lobes 5, long acuminate, pubescent within; petals obovate, rounded at apex, below tapering gradually to the short but broad claw. Stamens in 26 flowers examined vary in number from 7 to 18 with an average less than 15, filaments slender, 7 to 8 mm. long, anthers lemon-yellow, not well filled; styles slender, 4 to 7 in number, of equal length, 8 to 9 mm. long, stigmas small, capitate. A twig in flower as photographed in the greenhouse March 12, 1913, is shown as Fig. 65.

Fruit.—Roundish-oblate, base regular, apex conical and somewhat irregular; ground color yellow blushed in shades of red from bright crimson to very dark red; skin smooth, thin, tender; dots few, small, inconspicuous; cavity shallow, broad, obtuse, irregular; stem 25 to 35 mm. long, slender, oblique, glabrous; basin shallow, broad, obtuse, ridged; calyx small, open. Persistence of calyx lobes is not constant in this form; of 20 fruits examined 14 had normally persistent lobes and in 6 the lobes were deciduous. These fruits were weighed

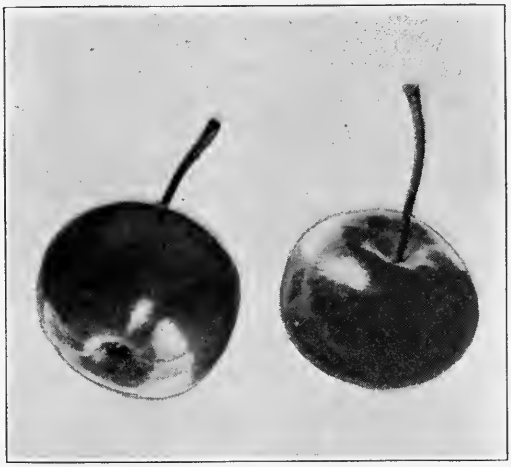

FIG 66.—FRUITS OF *M. prunifolia macrocarpa* (837), NATURAL SIZE, AUGUST 17

This fruit is yellow in color, blushed in shades of red from bright crimson to very dark red.

and measured; the average is found to be as follows; weight 6.72 grams; longitudinal diameter 20 mm.; transverse diameter 25 mm. In seed production the fruits were much above the average for the crab group; this form has an average of 7 seeds to each fruit. Two fruits of No. 837 photographed August 17, 1916, at full maturity, from one of the top-grafted trees are shown in Fig. 66. This form of *M. prunifolia* has been used as female in eleven crosses, six of which failed in fruit production, in one seeds did not germinate, and in one the seedlings died soon after appearance above ground. Only three crosses are represented by progeny in orchard; a cross by *M. siberica frutico coccinea* (19643) by twenty-six trees, eleven years old, one by Oldenburg by seven trees eight years old, and one by Jefferis by 130 trees seven years old. For the group there were 438 pollinations yielding 62 fruits or 14.15 percent of the pollinations successful. The variety has not been used as a pollen parent.

30. *Malus prunifolia* var. (838)

Represented in the collection by six trees grown from root-grafts made with the scions received from the Arnold Arboretum in January,

FIG. 67.—TREE OF *M. prunifolia* VAR. (838) PHOTOGRAPHED OCTOBER 15. FIG. 68.—SHOOT IN FLOWER PHOTOGRAPHED APRIL 29

The tree of this species is of erect, symmetrical habit. Flowering is inclined to be profuse, the flowers on some shoots being so concentrated that the leaves are entirely obscured. The twig in Fig. 68 was photographed after the petals had partly fallen.

1908. This is No. 838, which in habit of growth and manner of flowering appears much as does No. 837 described above.

The trees, now sixteen years old, are similar and of erect symmetrical habit; the bark of trunk and branches is light greenish-brown, that of twigs bright reddish-brown. Flowering twigs are glabrous, but the more robust non-flowering shoots are covered with close pubescence

which is retained thru the season. The largest tree is 20 feet high, has an extreme spread of 14 feet 8 inches, and a trunk diameter of 6 inches, the other trees are but slightly under these dimensions. Habit is illustrated in Fig. 67 from photograph taken October 15, 1913.

Leaves.—Elliptical, ovate or oblong, 3 to 4½ inches long, ¾ inch to 2 inches wide, acute, or acuminate, serrate or coarsely dentate, glabrous above even when young. The lower surface of young leaves is scantily covered with a short pubescence, in age some leaves lose this pubescence entirely, others retain it, or at least part of it until they fall; texture somewhat thick and leathery.

Flowers.—In this variety the flowers develop chiefly from lateral buds occurring along terminal shoots. Commonly all buds within a zone beginning 2 to 4 inches from the apex of the shoot and extending down from 4 to 12 or 15 inches contain flower clusters, while buds about the tip and below the zone are leaf buds only. The flowering thus concentrated on numerous erect shoots masses the color and adds to the beauty of the tree when in flower. Flowers are also produced from terminal buds of short spurs on lower branches, but these are so scattered as to attract no attention. Some clusters have 4 or 5 flowers, but most of them have 6. Pedicels 32 to 44 mm. long, slender, sparsely pubescent. Leaves are somewhat in advance of flowers but the long pedicels bring the flowers out so that when open they are fully exposed. Shoots in flower often appear as in Fig. 68, where flowers are in contrast with the light green leaves, but on some shoots the flowers are so concentrated that the leaves are entirely obscured. The figure given is from a photograph taken April 29, 1915, after petals had partly fallen. Buds globular, light pink, becoming ovate in form and fading to nearly white. As the bud cluster opens the axis elongates somewhat and there is some vertical separation of the points of attachment of pedicels, an arrangement that suggests the raceme, rather than the umbel or cyme. Ovary glabrous, calyx lobes 5, linear, acute, 7 mm. long, 2 mm. wide at base, pubescent on the inner surface, glabrous on the outer, frequently more or less tinged with red. Petals 5, oval in form, 20 mm. long, 12 mm. wide, rounded at apex and tapering abruptly to the short claw, mostly pure white, occasionally with a pink or pale rose-purple tinge. Stamens in 33 buds examined range in number from 16 to 24 with an average of 20, filaments slender 5 to 7 mm. long; anthers plump, light yellow. Styles 5, slender, 11 mm. long, longer than the stamens, connate 3 mm. from base, glabrous at base for 1.5 mm., hairy 1.5 mm. in either direction from the point of separation; stigmas elongated, oblique, irregular in form.

Fruit.—Round or slightly oblate, somewhat conical, varying greatly in size on the same plant. The extremes in weight for 350 fruits are 2.15 grams and 8.06 grams, the average is 6.55 grams. From these fruits the average diameters are found to be 20 mm. longitudinal

and 23 mm. tranverse. Base regular, ribbed, sides equal; color a clear yellow; occasionally fruits are found having a bronze blush over restricted areas and rarely this blushed area becomes pink. Bloom moderately abundant, powdery, gray, skin smooth, thin, tender, dots few, of medium size, areolar with russet center, inconspicuous. Cavity medium in depth, narrow, acuminate, regular; stem long, 32 to 44 mm.,

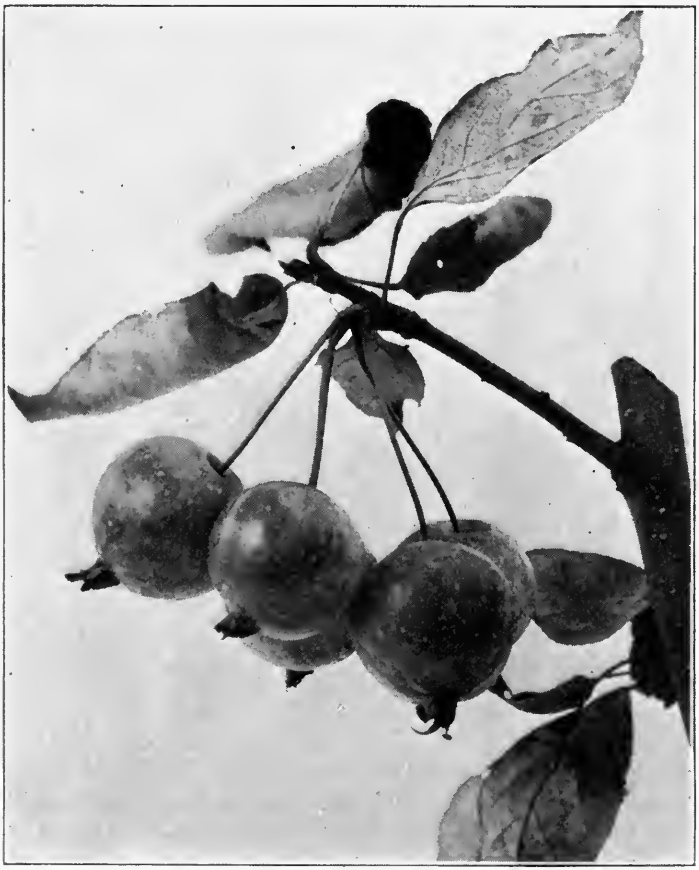

FIG. 69.—CLUSTER OF FRUIT OF *M. prunifolia* VAR. (838), SEPTEMBER 16

green, or late in the fall becoming red, glabrous. Calyx large, pubescent, closed; basin shallow and narrow or often none, usually ribbed about the bases of the long slender, acute reflexed, commonly persistent calyx lobes. In this matter of calyx lobes there is not perfect constancy. In 1915, of 2,239 fruits examined with special reference to

this character 2,114 or 94.41 percent had persistent lobes and 125 or 5.59 percent had deciduous lobes; in 1916 the examination included 2,316 fruits, in all but 4 of which the lobes were persistent, that is to say 99.82 percent were persistent and 0.18 percent deciduous. Considering the total 4,559 fruits in the two seasons, 4,430 or 97.17 percent retained the calyx lobes, while for 129 fruits or 2.83 percent the lobes were regularly deciduous. Core large, oblate, median, open; carpels roundish, emarginate, tufted, deeply concave. Flesh yellowish, tender,

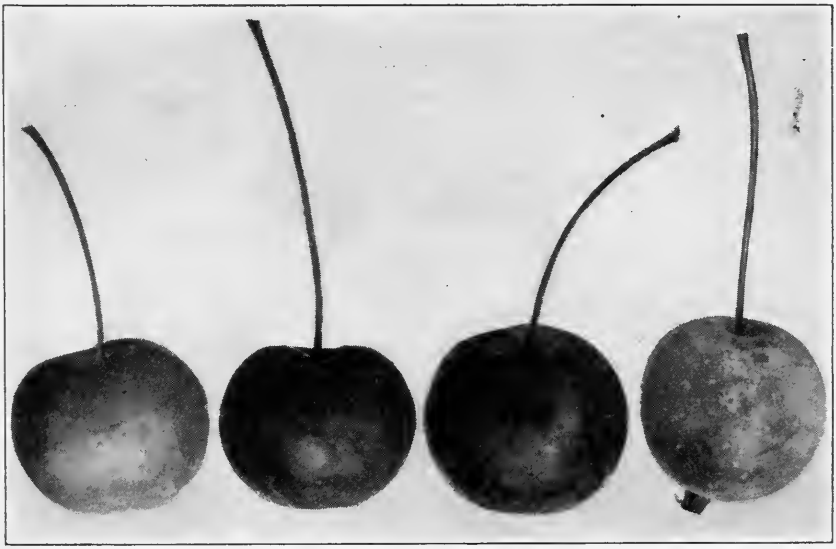

FIG. 70.—FRUITS OF FOUR OF THE CRAB FORMS OF MALUS

Left to right: *M. baccata* (red fruit) (806), *M. baccata* (red fruit, late) (807), *M. baccata maxima* (810), *M. prunifolia* var. (838).

crisp, moderately juicy, acid. A cluster of fruits from terminal bud of a short spur is shown in Fig. 69 from a photograph made September 16, 1915. A single fruit is to be seen at the extreme right in Fig. 70, in contrast with three forms of *M. baccata.*

This form of *M. prunifolia* has been used as female in 22 crosses with pollen from 15 varieties and 3 crab forms and only one, an attempted cross by Stayman Winesap, failed in maturing fruit; two other crosses, one by *M. toringo,* and one by *Arkansas,* passed out because of low vitality of seedlings. There are 19 crosses represented by 817 seedlings in orchard at ages from 7 to 13 years. The aggregate of pollinations is 1,089; they matured 651 fruits or were 59.77 percent successful. This is a high degree of success and ranks the female parent as one of the best breeders in the collection.

This same form has been used as the pollen parent in 19 crosses on 15 varieties and one crab. Five attempts failed and 14 crosses are represented in orchard by 948 seedlings now 7 to 13 years of age. It is a coincidence that the number of pollinations is the same as in the group where this crab was used as female, 1,089; the number of fruits matured is 287, giving 26.35 as the percentage of successful pollinations. This is a good percentage altho less than half that attained when the plant served as female parent.

31. *Malus prunifolia xanthocarpa* (839)

Rather indifferent success has attended the propagation and maintenance of this number in the Station collection. Ten root-grafts made with the scions received in January, 1908, all failed. On April 7, 1908, two scions, reserved for the purpose, were top-worked on a Virginia Crab seedling; these lived and grew, but the union obtained was less perfect than with most other forms grafted at the same time. Scions from the grafts of 1908 were worked on the lower branches of the stock March 11, 1911, and on October 25 the tree appeared as in Fig. 71, from photograph taken on that date. In February, 1913, this tree was shifted with others to another tract: in 1914 the trunk was attacked by blight and the tree died.

Scions from the top-graft were grafted on a potted paradise stock February 21, 1910. This tree has been forced each season since: it flowered and fruited in 1914 and again in 1916, and the flowers and fruits from the greenhouse are the only ones thus far produced by this variety of Malus. With scions from the same source root-grafts were made in February, 1912, they were planted out in the spring and some made a feeble growth, but all were dead in the fall. Other scions were top-worked on a Grimes stock April 4, 1912. These scions grew feebly for two seasons and died in 1914. Thus the only representative of No. 839 is the dwarf tree on paradise stock. So far as can be judged from the growth made by top-grafts the tree habit is upright and in every way similar to Nos. 837 and 838.

Leaves.—Ovate or some of the smaller elliptical, 2 to 4½ inches long, 1 to 2¼ inches wide, acuminate, crenate or dentate, glabrous both sides; petioles rather short, stout, glabrous, at least when mature; stipules lanceolate, petioled, mostly persisting.

Flowers.—Those produced in the greenhouse in 1914 were from terminal buds of shoots or short spurs. Pedicels slender, 15 to 17 mm. long, slightly pubescent, light green. Calyx lobes 5, acuminate, 7 mm. long and 1.5 mm. wide at base, separated somewhat at base, glabrous outside, heavily pubescent within. Petals 5, light pink in bud, fading to white in open flowers, oval, 11 mm. long and 8 mm. wide with very short claw. Flower expands 26 mm. Stamens vary in number from 15

to 21, but a large majority of the flowers examined have the normal number 20; filaments slender, 5 to 6 mm. long, anthers plump, light yellow. Styles unequal in length, 5 to 9 mm. long; in 58 flowers examined 50 had 5 each, 6 had 4 each, 1 had 2, and 1 had 1; erect, glabrous; stigmas oval, oblique.

FIG. 71.—TOP-WORKED TREE OF *M. prunifolia xanthocarpa* (839)

The propagation and maintenance of this species have not been very successful at this Station. The tree illustrated here was top-worked April 7 and March 11, and was photographed October 25 of the same year.

Fruit.—Small, oblong, irregular at base, truncate and irregular at apex, sides unequal, ground color yellow, blushed with an over-color of light red which in some fruits deepens almost to dark red. Skin smooth, thin, tough, dots few, small, regular, round, white, inconspicuous; cavity moderately deep, medium in width, acute, irregular. Stem slender, 24 mm. long, erect, green, pubescent; the average weight of 3 fruits is 1.1 grams; average longitudinal diameter 12 mm., transverse diameter 11 mm.; calyx lobes deciduous in all fruits; core large, elliptical, sessile, closed. Cells axile, variable in form; carpels elliptical, emarginate, glabrous, moderately concave. Flesh yellowish, tender, moderately juicy, subacid. Used as female in six crosses, four of which failed. A cross of Domine in 1914 from 47 pollinations matured 4 fruits; only 1 of 3 seeds germinated and this seedling now in its tenth year grades as "good," is 12 feet 7 inches high, has spread of 7 feet 1 inch and a diameter of 3.3 inches. One other cross by *M. prunifolia* var. (19651) from 49 pollinations matured 22 fruits with 25 seeds, only 1 of which germinated; this seedling now in its seventh year is graded as "good," has a height of 5 feet 4 inches, a spread of 4 feet 7 inches, and is 1.2 inches in diameter. Thus the group with 158 pollinations was approximately 19 percent successful in fruit production, but is represented in orchard by only two seedlings. As a pollen parent this form of Malus was used in

thirteen crosses, nine of which failed; the four crosses maturing fruits are represented in orchard by nineteen trees. For the group the 162 pollinations were 11.72 percent successful.

32. *Malus prunifolia* var. (856)

The scions for this number in the Station collection came from the Arnold Arboretum in January, 1908, and were labelled "Malus sp? No. 5004." The tree from which the scions came is one of several seedlings grown from seeds collected by Dr. C. S. Sargent in Japan in 1892; it has not attained large size and exhibits the characteristics of the *prunifolia* group. This variety is represented in the Station collection by one tree now in its seventeenth year from root-graft made January 11, 1908, and two trees, also in the seventeenth year, top-worked on Virginia Crab seedlings April 9, 1908. The top-grafts of 1908 began flowering in 1911 and have bloomed abundantly each year since. Fig. 72 from a photograph of one of these trees taken May 9, 1916, shows fairly well the possibilities of this variety as an ornamental. The tree root-grafted in 1908 did not flower until 1914 and not until 1916 was the bloom abundant. This tree now has dimensions as follows; height 15 feet 7 inches; spread 18 feet 5 inches, trunk diameter 7.2 inches. All trees are vigorous, of erect habit at first, becoming spreading. Foliage very dense. The bark of trunk and larger branches is dark olive-green, twigs reddish-brown, glabrous.

Leaves.—Large, 3 to 6 inches in length, 1 to 2¼ inches wide, oval, or elliptical, tapering equally above and below, acuminate, crenate or bluntly serrate, slightly pubescent on both sides when young, becoming glabrous thruout; petioles slender, ¾ inch to 2 inches long, glabrous at maturity.

Flowers.—Produced from terminal and lateral buds of shoots of the preceding year and to some extent from terminal buds of short spurs from older wood. In numbers of buds to the cluster there is about equal division between clusters having 5 buds and those having 6. Young buds are globular, exceeded in length by the connivent tips of the calyx lobes; in development they elongate, equalling or slightly exceeding the calyx lobes, light pink fading to white. The slender, scantily pubescent pedicels elongate as the buds enlarge, becoming 30 mm. to 35 mm. in length before the flowers open; this length is sufficient to extend the buds beyond the leaves so that they are conspicuous; ovaries covered with a dense close pubescence; calyx lobes linear, acuminate, 9 mm. long, 2 mm. wide, glabrous without, margin and inner surface pubescent.

Flower expands 30 mm. to 35 mm.; petals oval or obovate, rounded at apex, tapering at base to a short but distinct claw, 14 mm. to 17 mm. long, 8 mm. to 10 mm. wide, pure white. Stamens 20, fila-

ments slender, 8 mm. to 10 mm. long, anthers plump, light yellow. Styles 5, slender, 11 mm. long, connate 4 mm. up from base, glabrous at base, but slightly hairy beginning 1 mm. from base and extending up 5 mm. to 6 mm., stigmas small, oval, oblique.

FIG. 72.—TOP-WORKED TREE OF *M. prunifolia* var. (856) IN BLOOM

The tree illustrated here is a top-graft of 1908, which began flowering in 1911 and has bloomed abundantly each year since. The photograph, which was made May 9, 1916, shows the possibilities of this variety as an ornamental.

Fruit.—Small, individual weight as averaged from 100 fruits is 2.18 grams; uniform in size, vertical diameter 14 mm., transverse diameter 15 mm.; pedicels slender, erect, 35 mm. long, glabrous. Most fruits are uniformly yellow, occasionally a small area exhibits a bronze blush. Cavity medium in depth, broad, angular; basin shallow, broad, often prominently ribbed; calyx lobes in part persistent and in part

deciduous; of 5,270 fruits examined in regard to this character 3,048, or 57.83 percent, had persistent lobes and 2,222, or 42.17 percent, had deciduous lobes.

Core medium in size, nearly globular, nearly sessile, closed; cells axile, uniform; carpels ovate, emarginate, seeds plump, rather small, light brown. Flesh yellowish, firm, juicy, subacid. As to number of cells the 100 fruits examined divide as follows. Seven had 3 cells each, 49 had 4 each, and 44 had each the normal 5 cells. The number of plump, apparently good seeds is 497, an average of 4.97 to each fruit; this gives this form of malus an intermediate position in seed produc-

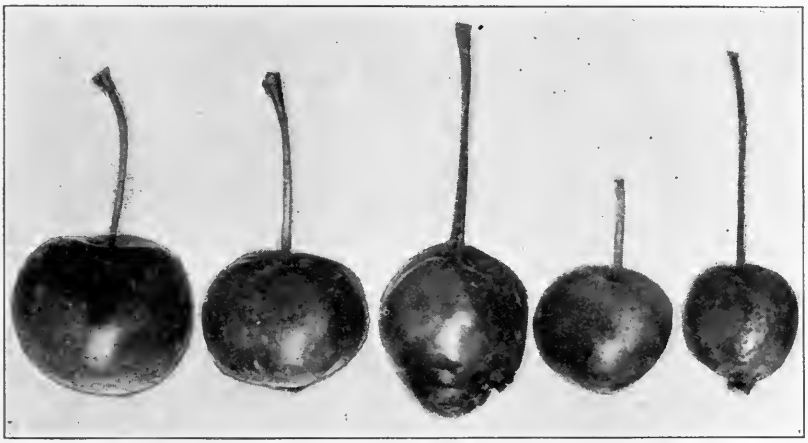

FIG. 73.—FRUITS OF FIVE OF THE CRAB FORMS OF MALUS, NATURAL SIZE

Left to right: *M. siberica frutico coccinea* (19643), *M. scheideckeri* (19646), *M. spectabilis* (848), *M. ringo* (840), *M. prunifolia* var. (856).

tion, for of 25 crab-like forms for which record has been made the average seed production is 4.22 seeds to each fruit; 13 forms have averages less than for *M. prunifolia* (856) and 11 forms have higher averages. The maximum of 7.80 is attained by *M. malus fl. pl.* (833) and the minimum of 1.32 falls to *M. fusca* (841). A single fruit of *M. prunifolia* (856) is shown in Fig. 73.

33. *Malus prunifolia* var. (19651)

Scions from which trees of this variety of Malus were grown were included in the lot received in January, 1907, from the Arnold Arboretum thru the U. S. Department of Agriculture. They bore the number 19651 and were labelled *M. arnoldiana.* Long before the trees produced flowers and fruits it was observed that they were different

from those labelled *M. arnoldiana* under the number 802. When fruiting began it was definitely determined that No. 19651 represents a form of *M. prunifolia* and that it is distinct from any other form in the collection. This variety of *M. prunifolia* is represented in the collection by one tree from root-graft of January, 1907, and one

FIG. 74.—TREE OF *M. prunifolia* VAR. (19651) NINE YEARS FROM ROOT-GRAFT

This species is erect in habit when young; the shoots bend outward when fruiting begins, and after two or three crops the tops become wide-spreading. The tree shown here, from a root-graft of 1907, was photographed when nine years old.

top-worked tree grafted in 1912. When young the trees are erect in habit; when fruiting commences the long willowy shoots are bent outward; and after bearing two or three crops the tops become wide-spreading. The tree from root-graft in 1907, as photographed September 24, 1915, when nine years old, is shown in Fig. 74. This tree as measured in the fall of 1923 is 17 feet 2 inches high, has an extreme spread of 21 feet 2 inches, and a trunk diameter of 8.6 inches. The

trunk is smooth with dark cherry-like bark, twigs very dark reddish-brown, glabrous. Lenticels numerous and conspicuous.

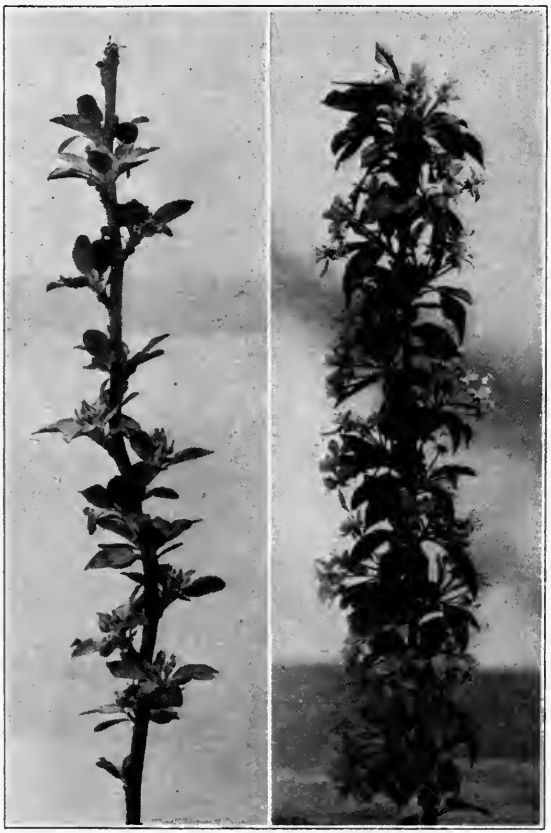

FIG. 75.—TWIG OF *M. prunifolia* VAR. (19651) IN BUD, APRIL 21. FIG. 76.—TWIG IN FLOWER, APRIL 30

The buds are dark pink, but are inconspicuous because the pedicels and bud axis are short, and leaves hide the cluster. As flowering continues, the pedicels and bud axis elongate, and the flowers are thrust out beyond the leaves. The flowers are nearly pure white when open.

Leaves.—Three to 4½ inches long, 1 to 1½ inches wide, oval or elliptical or some of the smaller approaching lanceolate, acute, coarsely serrate, glabrous above, sparingly pubescent along the midrib below; petioles stout, mostly about an inch in length, glabrous.

Flowers.—Borne from terminal and lateral buds on terminal shoots. Buds dark pink, but inconspicuous in early stages of development because pedicels and bud axis are both short and leaves hide the cluster; 4 to 8, mostly 5 buds to each cluster. As development proceeds the bud axis elongates, becoming from 12 to 18 mm. in length; the

FIG. 77.—FRUITING BRANCH OF *M. prunifolia* VAR. (19651), SEPTEMBER 16

This form retains its calyx lobes to a very marked degree; of 9,496 fruits examined, 88 or less than 1 percent had deciduous lobes, and of these 52 were only partially deciduous.

pedicels also elongate, reaching 22 to 30 mm. in length. The flowers are thus thrust out beyond the leaves and become conspicuous; they expand about 30 mm. and are nearly pure white when open. Pedicels and ovary pubescent. Calyx lobes triangular, acute, 5 mm. long, 2½ mm. wide at base, sparsely pubescent without, densely so within, erect in bud, becoming reflexed in open flowers. Petals elliptical, 16 mm. long, 8 mm. wide, with short claw. Stamens 20, filaments slender, 8 to 10 mm. long, anthers plump, light yellow. Styles vary from 3 to 5,

are 8 to 10 mm. long, connate ⅓ the length, and hairy from base to point of separation. Stigmas oval, more or less oblique. A twig in bud is shown in Fig. 75 and one in flower in Fig. 76.

Fruit.—Roundish oblong; the average of 4,000 fruits weighs 4.63 grams, has a longitudinal diameter of 18 mm., a transverse diameter of 21 mm., and produced 5.3 good seeds. Base regular, apex irregular, clear lemon-yellow in color; covered with a scanty, waxy, white bloom; skin smooth, thin, tough; dots few, small, white, inconspicuous; stem 28 mm. long, slender, erect, green, glabrous, cavity shallow, narrow, obtuse, regular; basin none, the flesh rounds up to the somewhat fleshy bases of the usually persistent calyx lobes. Very few of the crab forms of Malus retain the calyx lobes with as high constancy as does this; of 9,496 fruits examined 88 or less than 1 percent are recorded as having deciduous lobes, and of these 52 were only partially deciduous, that is to say, while 2, 3, or 4 of the lobes dropped off leaving the characteristic scar, there remained 1, 2, or 3 with the normal fleshy bases. Core of medium size, elliptical, or roundish, median, closed. Cells axile, carpels obovate, emarginate, glabrous. Seeds plump, of medium size, light brown; flesh white, firm, crisp, juicy, very acid. Fig. 77 showing fruiting characteristics is from a photograph made September 16, 1915. A single fruit may also be seen at the left below in Fig. 54, page 517.

34. *Malus ringo* (840, 19662)

This species is represented both as No. 19662 in the series propagated in 1907 and as 840 in the series of 1908. Trees of the two numbers are alike in all respects and probably both lots of scions came from the same tree. Present representation in the collection is as follows:

19662—Two trees in pots, one on paradise, one on Doucin, grafted Feb. 12, 1910. These have flowered each year since 1913.
One tree, in pot, on paradise, grafted March 5, 1913.
Five trees from root-grafts made January 22, 1914.
840—Two trees from root-grafts made January 18, 1908.
One tree top-worked on Grimes, April 6, 1912, and April 3, 1913.

The two trees from root-grafts of 1908, now sixteen years old, best exhibit the habit of this species. They are symmetrical trees with erect smooth trunks and somewhat spreading round tops. The average of the two sixteen-year-old trees is 14 feet 7 inches high, spread 23 feet, and has trunk diameter of 6.7 inches. The bark of trunk and branches is light brown with an olive-green tinge; twigs are reddish-brown, glabrous. The tree on paradise grafted March 5, 1913, is shown as photographed June 21, 1916, in Fig. 78.

Leaves.—Broadly ovate to oblong or elliptical, 2½ to 4½ inches long, 1 to 2¼ inches wide, serrate or coarsely crenate-dentate, acumi-

nate; when young densely white tomentose beneath and with scattered hairs on the upper surface, becoming glabrous above, but retaining some pubescence below; rather thick even when young, becoming thicker in age and somewhat rugose, dull green above and but little lighter in color below. Petioles ½ to 1 inch long, densely pubescent when young, becoming glabrous in age; stipules lanceolate, entire, or with occasional serrations, petiolate, caducous.

FIG. 78.—TREE OF *M. ringo* (19662) ON PARADISE

This tree was grafted March 5, 1913, and was photographed June 21, 1916.

Flowers.—These trees have bloomed yearly since 1913 and every second year since 1918 have flowered profusely. May 5 is the mean full bloom date for the last twelve years, while April 17, 1921, was the earliest, and May 17, 1917, the latest date for full bloom. The flower clusters come principally from terminal buds of shoots of the preceding year and of short spurs along the larger branches and also, to some extent, from lateral buds of terminal shoots. There is no crowding of clusters and massing of bloom as in most forms of *M. baccata* or of the forms of *M. prunifolia* thus far described. Flower clusters are scattered over the trees much as they are in the native species *M. ioensis*. Two-thirds of the clusters examined produced 5 flowers each, but the range in number was from 3 to 11. Of 140 clusters 1 had 3, 21 had 4 each, 93 had 5 each, 20 had 6 each, 1 had 8, and 1 had 11. Young buds are nearly globular and deep red in color; as they develop there is some elongation and the color fades to a dark pink. Pedicels stout, 15 to 28 mm. long, pubescent; calyx lobes short, broadly triangular, obtuse, pubescent both sides. Petals oval or nearly orbicular, rounded at apex, 13 mm. long, 10 mm. wide, claw short but distinct. Flowers expand 28 mm. From examination of 250 flowers it is found that stamens range in numbers from 12 to 25 with an average to each flower of a little above 19. Filaments slender, 3

to 6 mm. long, anthers plump, light yellow, containing abundant good pollen. Styles vary in number from 3 to 6 with an average of 4.82, slender, 8 to 9 mm. long, connate ⅓ the length, sparsely hairy about and just above the point of separation. Stigmas oval, oblique. Fig. 79 is a twig in bud as photographed in the greenhouse March 13, 1914. Buds expand with, or a little in advance of, the leaves and because of the dark red color are conspicuous and handsome.

FIG. 79.—TWIG OF *M. ringo* (840) IN BUD, MARCH 13

Buds expand a little in advance of the leaves; they are dark red in color and very ornamental.

Fruit.—Fruits are in clusters of from 3 to 6, roundish oblate, regular at base, apex irregular, ribbed; in cross-section most fruits exhibit 5 well-marked ridges; sides equal, weight and dimensions as averaged from 301 fruits are as follows; weight 3.24 grams, longitudinal diameter 15 mm., transverse diameter 18 mm. The average seed production as found from these same fruits is 5.79 seeds to each fruit, a number considerably above the average for the crab group. The color is for most fruits a brilliant crimson; this is blushed or washed

on over a greenish-yellow ground which, for most fruits, is entirely obscured. This high color adds much to the attractiveness of the tree in autumn, but the beauty is fleeting because soon after acquiring the brilliant color the fruits fall.

A moderately heavy, waxy, white bloom covers the fruits; skin smooth, thin, tough; dots few, small, regular, round, white, inconspicuous; cavity rather shallow, broad, obtuse, regular; stem stout, 15 to 25 mm. long, erect, pubescent. Basin shallow broad, obtuse, irregular,

FIG. 80.—TWIG OF *M. ringo* IN FRUIT, AUGUST 20

Fruits appear in clusters of three to six; most of them are a brilliant crimson, making the tree very attractive for a short period in autumn. The fruits fall soon after acquiring this brilliant color.

ribbed; the calyx lobes are deciduous as determined from examination of 1,401 fruits, but in many of the fruits the dehiscence is somewhat tardy; separation takes place, but the dried calyx still persists until in some way disturbed. The dried lobes are readily brushed off and then show the characteristic russet scar. The core is large, cordate, median, closed; cells axile, carpels obovate, emarginate, glabrous, usually deeply concave; flesh yellowish, firm, crisp, juicy, acid. Two clusters

of fruits, from pollinations made in the spring, are shown as photographed August 7, 1914, in Fig. 80. A single fruit is also shown second from the right in Fig. 73, page 541. The characteristics of *M. ringo* indicate a hybrid origin. Leaf and tree characters most resemble *M. prunifolia,* but the fruit characters, particularly in regard to the deciduous calyx, point to *M. baccata* as one of the probable progenitors. It was introduced in Europe more than fifty years ago by Dr. von Siebold, coming as a cultivated plant from Japan. How long it had been under cultivation there, what species it had opportunity to mingle with, or how many generations of seedlings preceded the present form are matters unknown and past finding out. The history of the plant is entirely unknown and possible ancestors can only be assumed from study of the characters possessed by the plant as it now exists.

35. *Malus ringo sublobata* (854, 19689)

Scions of this form of Malus were received from the Arnold Arboretum thru the U. S. Department of Agriculture, in 1907, under the number 19689. Other scions were received in 1908 direct from the Arboretum, but under the name *Malus toringo sublobata.* This went into the Station collection under the serial number 854. The trees grown from the two lots of scions were carried in the records under the respective numbers until flowers and fruit were produced, when it became evident that the two were identical. Later the identity of the plants grown here with the original tree in the Arnold Arboretum under the name *Malus ringo sublobata* was established. This tree in the Arboretum was received from Germany about twenty-five years ago as *Pyrus ringo sublobata.* It was transferred to the genus Malus, and recently Dr. Alfred Rehder has determined it as *Malus prunifolia rinki,* basing this determination upon material collected in Japan in 1914 by Professor J. G. Jack. Representation in the collection is as follows:

19689—One tree from root-graft made January, 1907, and now seventeen years old.
Two trees from root-grafts made in 1914.
854—Two trees from root-grafts made January, 1908, and one tree top-worked on Virginia Crab in 1908.

Trees of erect habit, branches numerous, inclined to be long and slender, in fruit curving outward and bending low. Bark of trunk and branches smooth, light brown with a distinct tinge of olive-green; twigs dark reddish-brown, glabrous. The tallest tree measures 15 feet, has a spread of 14 feet 5 inches and a trunk diameter of 6.1 inches; dimensions of other trees are but slightly less. One of these trees as photographed September 24, 1915, is shown in Fig. 81.

Leaves.—Ovate, oblong or elliptical, some of the small ones lanceolate, 2 to 4 inches long, ¾ to 1¾ inches wide; irregularly coarsely

serrate, acute or shortly acuminate, densely white tomentose below and with some scattered hairs above when young, becoming glabrous both above and below. Petioles ½ to 1 inch long, stout, pubescent

FIG. 81.—TREE OF *M. ringo sublobata* (19689) NINE YEARS FROM ROOT-GRAFT

The tallest tree of this species now growing at this Station is 15 feet high, and has a spread of 14 feet 5 inches; the others are slightly smaller. The one shown here was photographed September 24, 1915.

when young, becoming glabrous. Stipules ¼ to ¾ inch long, lanceolate, petiolate, persisting on some leaves.

Flowers.—Young plants flower first from terminal buds, the second year of flowering a few lateral buds, usually just below the ter-

minal bud, produce flowers; this flowering portion of the shoot becomes longer each year, in some cases approximating 2 feet in length. The internodes are short, bringing clusters near together, thus massing the

FIG. 82.—TREE OF *M. ringo sublobata* (854-4) IN FLOWER MAY 9, 1916

The flowering portion of the shoot (the terminal bud and a few adjoining lateral buds) becomes longer each year, in some cases reaching a length of nearly two feet. The internodes are short, bringing the clusters near together and massing the bloom attractively.

bloom and adding to the attractiveness of the tree when in full bloom. Fig. 82 illustrates one of the trees as it appeared when photographed May 9, 1916. In bud the pedicels are short and the buds obscured by the young leaves; later the pedicels elongate and become an inch or more in length by the time the flowers are open. Buds are oblong, rounded at apex, dark reddish-pink; the number in each cluster is variable and has rather an extreme range, from 2 to 16. In 579 clusters examined the distribution was as follows:

Number of buds to the cluster	2	3	4	5	6	7	8	9	10	11	12	14	15	16
Number of clusters	2	3	32	134	230	88	36	28	12	6	4	1	1	2

The petals fade as the buds open and when the flowers, which expand about 30 mm., are fully open they are white, somewhat streaked with light pink. Calyx lobes 5, triangular acuminate, 5 mm. long and 2 mm. wide at base, pubescent both sides, erect in bud, becoming reflexed in open flowers. Petals 5 to 7, ovate to elliptical with short, but distinct claws. Stamens 8 to 10, filaments slender, 4 to 8 mm. long, anthers plump, light yellow; styles 4 or 5, slender, about 8 mm. long, connate ¼ the length, hairy from base to above the point of separation. Stigmas oval, oblique, and somewhat prolonged down the style.

Fruit in clusters of 2 to 5, oblong, conical, regular at base and apex, cross-section obscurely ribbed, sides equal. The average weight and dimensions as determined from 5,800 fruits are as follows:—weight 6.33 grams, longitudinal diameter 22.91 mm., transverse diameter 22.52 mm. Color dull yellow, sometimes with bronze blush on one side, a moderate amount of waxy white bloom. Skin rough with irregular russet dots and splashes. Cavity medium in depth, rather narrow, acute; stem short, 13 to 25 mm. long, slender, glabrous. Basin in fruits having deciduous calyx lobes is represented by a very slight depression which is narrow and obtuse; in fruit with persistent calyx lobes the surface rounds up to the fleshy bases of the lobes and there is entire absence of depression.

In the matter of retention of calyx lobes there is a division in this form of Malus; in some fruits they persist while in others they are deciduous. In 1915, 1,943 fruits were examined in regard to this character and 438 or 22.54 percent found to be deciduous. In 1917 all available fruits were examined and the record for each of eleven trees was kept separately. The numbers of fruits for individual trees range from 373 for a tree top-worked in 1912 to 4,998 for a tree root-grafted in 1908. The aggregate of fruits is 23,671, and of this number 6,666 or 28.16 percent have regularly deciduous calyx lobes.

All of the trees from which these fruits were taken were propagated by grafting from a single individual, and it seems reasonable to expect uniformity in the proportion of fruits having deciduous calyx lobes, but the individual trees vary greatly in this respect. While the percentage of fruits with deciduous calyx lobes is for all fruits 28.16, for individuals the range is from 14.28 percent for a tree having 2,234 fruits and 15.46 percent for a tree having 3,831 fruits to 57.13 percent for a tree having 4,998 fruits. Of the eleven trees four are each less than 20 percent deciduous, five have percentages between 20 and 30, one has 36.73 percent, and one has 57.13 percent. This appears to be a very wide range of differences for so distinctive a character and as

yet no satisfactory explanation has suggested itself. Core of medium size, elliptical, median, closed; cells axile, carpels ovate to oblong, sometimes obovate, emarginate, glabrous, moderately concave, seeds plump, of medium size, color a medium brown. The fruits are quite low in seed production; as averaged from 5,800 fruits there are 3.61 seeds to each fruit. Only two of the crab group fall below this average, namely—*M. fusca*, with an average of 1.32, and *M. atrosanguinea*, with an average of 2.02 seeds to each fruit. The average for all fruiting crabs in the collection is 4.22 seeds to each fruit. Flesh yellowish, firm, crisp, rather dry, acid. Fig. 83 is from a photograph taken September 16, 1915. *M. ringo sublobata*, under the two numbers 19689 and 854, has served as the female parent in twenty-eight crosses, nine on trees in orchard and nineteen in the greenhouse. Sixteen varieties and three crab forms were used as male parents. The aggregate of pollinations made was 2,013, and 897 fruits representing 44.56 percent of the pollinations matured. For individual crosses the percentage of success ranged between 24.1 percent and 100 percent. The degree of success attained was high and this form may be rated as successful as a female parent. The variety is not available as a male parent because it produces no viable pollen. Anthers removed from flowers dry up and do not dehisce; when broken mechanically no fully developed pollen grains are found.

FIG. 83.—FRUITING TWIG OF *M. ringo sublobata*, SEPTEMBER 16

An abnormality not found, or at least of very rare occurrence, in other forms of Malus is quite common in this variety and that is the production of 2 or in some cases 3 flowers on the same pedicel. This occurs, with rare exceptions, in terminal clusters. The point of branching varies greatly; most frequently it is near the distal extremity of the pedicel, but sometimes occurs near the middle or in some cases near the base. Where branching occurs near the end of the pedicel the

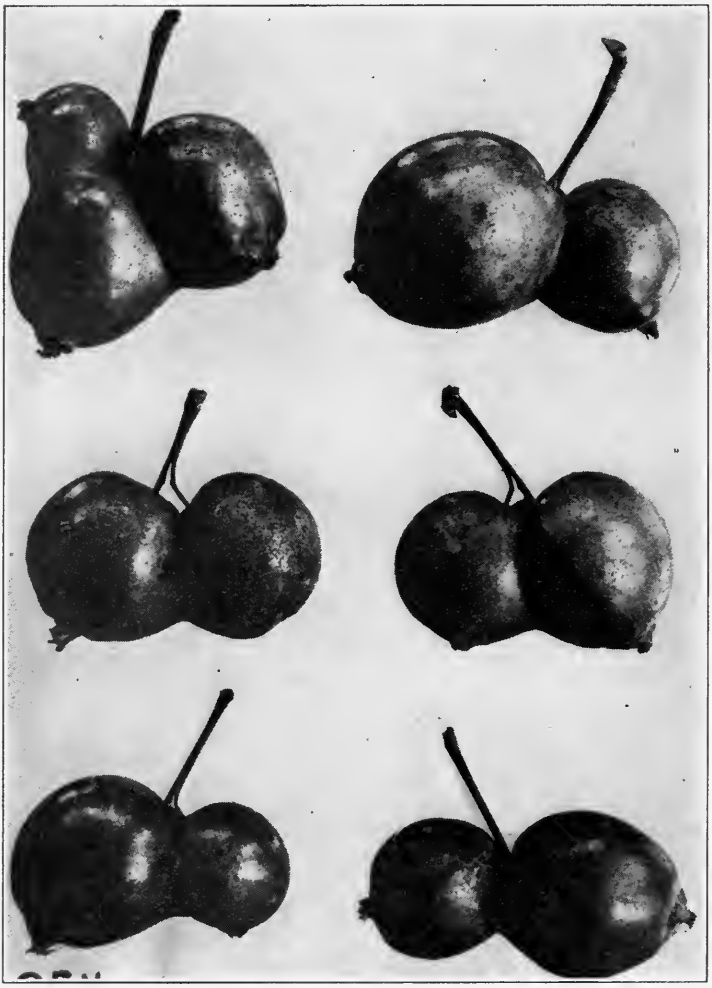

FIG. 84.—TWIN FRUITS OF *M. ringo sublobata* (854), SEPTEMBER 14

This abnormality appears as a characteristic of the variety. Nearly 200 cases of this union of fruits following the appearance of flowers on branches of pedicels are recorded for this variety of Malus in 1916, and none for any other variety. The twinned fruits are sometimes equal in size, but often the fruit terminating the pedicel is larger than that terminating the branch.

ovaries are in such close contact that they invariably grow together; the area involved in the union is greater or less according to the positions occupied by the ovaries and the length of the pedicel branch. In some cases a branch is so short as to become entirely imbedded in the developing fruits which then take a nearly horizontal position with the apexes at the extreme of possible separation; in other cases the branches are long enough to remain free and the apexes of the fruits point obliquely downward and vary in degree of separation according to the extent of the union. Where the branches are long no union of ovaries takes place and sometimes the two fruits developed on the one pedicel are equal and normal in size. Equality in size of twinned fruits is not rare, but in many pairs the fruit terminating the pedicel is larger than that terminating the branch. Not infrequently the fruit on the branch remains quite small and cases are found in which the small fruit becomes almost entirely invested by the larger. Nearly 200 cases of this union of fruits following the appearance of flowers on branches of pedicels are recorded for this variety of Malus, in 1916, and none for any other variety. The abnormality appears as a characteristic of the variety. Several forms of these united fruits are shown in Fig. 84, which is from a photograph made September 14, 1915.

36. *Malus sargenti* Rehder. Sargent, C. S. Trees and Shrubs 1, p. 71. 1905

Represented in the collection by one tree from root-graft made January 11, 1908, now in its seventeenth year; a small and shrub-like tree 7 feet 2 inches high, with a spread of 12 feet 9 inches, and a trunk diameter of 5.1 inches. The tree has flowered and fruited abundantly each year since 1913. Its appearance when nine years old as photographed May 9, 1916, is shown in Fig. 85. There is also one tree top-worked on Virginia Crab, April 8, 1908, and one tree grafted in February, 1910, on potted Doucin stock. This dwarf tree in greenhouse has flowered each year since 1913 and has been used in crosses. The tree on Virginia Crab as it appeared four years from grafting is shown in Fig. 86 from photograph October 25, 1911.

Low, thick, shrubby growth with somewhat tortuous branches is characteristic of this species. Bark of trunk and large branches dark brown, conspicuously marked with numerous large, dull straw-colored, transversely elongated lenticels; twigs and smaller branches reddish-brown.

Leaves.—Leaves of flowering shoots small and extremely variable in form, from narrowly lanceolate to ovate, elliptical, and even orbicular, sharply serrate or often nearly entire on the lower half. On non-flowering shoots ovate or oblong-ovate, or some of the smaller elliptical, 1½ to 3¼ inches long, ¾ inch to 2¼ inches broad; many are

3-lobed, the central lobe much larger than the two lateral lobes and sometimes this is so notched above as to give the appearance of 5 lobes; irregularly sharply serrate, apex acute, base rounded, often subcordate; sparingly pubescent both sides when young, becoming glabrous above and, in the fall, sparsely villous below. Petioles slender, ½ to 1 inch long, pubescent when young, but nearly glabrous when

FIG. 85.—TREE OF *M. sargenti* (843) NINE YEARS OLD

From root-graft made January 11, 1908. This tree, which was photographed May 9, 1916, has flowered and fruited abundantly each year since 1913.

mature; stipules minute and caducous below, on leaves above, foliaceous, lanceolate, remotely serrate, inclined to persist.

Flowers.—Produced in profusion from terminal and lateral buds of spurs and twigs; the number of buds to a cluster was as follows for 30 clusters counted; with 3 buds 1, with 4 buds 1, with 5 buds 4, with 6 buds 17, with 7 buds 6, and with 8 buds 1. The buds are reddish-pink at first, but soon fade; each petal becomes white except at the margin which retains the pink, imparting to the buds a striped appearance that is quite characteristic; another peculiarity that serves to distinguish readily the buds of this species from those of any other

Malus in the collection is the folding in of the tips of the petals at nearly a right angle, giving a truncated or flat-topped appearance. Frequently the styles protrude in the center while the buds are quite young. Flowers expand 18 to 20 mm. Pedicels are slender, 20 to 25 mm. long, green, sparsely pubescent; the ovaries are glabrous. Calyx lobes rather broadly triangular, acuminate, 4 mm. long and 2 mm.

FIG. 86.—TOP-WORKED TREE OF *M. sargenti* (843) FOUR YEARS FROM INSERTION OF SCIONS

This tree is characteristically low, thick, and shrubby in growth, with somewhat tortuous branches. The bark of the trunk and large branches is dark brown, marked with large, straw-colored, crosswise lenticels.

broad at base, glabrous outside, pubescent on margins and inside, erect in bud, becoming about horizontal in open flowers; tips are not reflexed; the calyx lobes are regularly deciduous soon after the flowering period. To obtain more definite information regarding the constancy of this character of deciduous calyx lobes, 1,000 fruits were examined with special reference to the calyx lobes without bringing to light any departure from regular deciduousness either in time, manner, or char-

acter of the scar left; the lobes are deciduous in all fruits and in the same way: evidently the species is pure as to this character. Petals 5, oblong or oval, rounded at apex, 9 mm. long, 5 mm. broad, subcordate, claw short, but distinct, 1 mm. long. Stamens 18 to 20, filaments rather stout, 3 to 6 mm. long; anthers plump, yellow, pollen orange. Styles 3 to 5, most commonly 4, 7 mm. long, connate for 2 mm. from base and glabrous except for a narrow ring of hairs immediately about the point of separation; stigmas irregularly oval, oblique. Fig. 87 is from photograph of a twig of this species in bud.

FIG. 87.—TWIG OF *M. sargenti* (843) IN BUD, MARCH 19

The buds have a characteristic pink and white striped appearance; they are also distinguished easily from those of any other Malus in the collection by the folding in of the tips of the petals at nearly a right angle, which gives them a flat-topped appearance.

Fruit.—Round, regular at base and apex in transverse section, sides equal. The average of 223 fruits weighed and measured is a fruit weighing .56 gram, with a longitudinal diameter of 8½ mm. and a transverse diameter of 9½ mm. These fruits had cells as follows: with 2 cells 1, with 3 cells 22, with 4 cells 141, with 5 cells 59. Color a uniform dark red, becoming very dark, almost black in late fall. After frosts the fruits become very soft and soon dissolve and disappear, leaving the pedicels upon the tree. Skin smooth, of medium thickness, tough; dots few, small, regular, round, gray, inconspicuous; cavity shallow, moderately broad; acute, regular; stem long, 20 to 25 mm., slender, erect, green, glabrous; calyx lobes uniformly deciduous; basin shallow, broad, obtuse, slightly ribbed. Core of medium size, elliptical, median, closed; carpels roundish, entire, glabrous, moderately concave; flesh yellowish, rather dry until touched by frost, then becoming watery, acid.

A fruiting branch, ⅙ natural size, is shown in Fig. 88 from photograph of October 18, 1916, and a single fruit appears, natural size, the fourth from the left in Fig. 44, page 498, where comparison is afforded with fruits of several other species. This species was discovered by Dr. C. S. Sargent in a "brackish marsh near Mororan, Japan, in 1892

and introduced by him into cultivation." It was described and named by Dr. Alfred Rehder and published by Dr. C. S. Sargent.[1] Affinities of the species are given by Dr. Rehder as follows:

"*Malus Sargenti* is most nearly related to *Malus Toringo Sieboldi,* differing from it chiefly in its larger, pure white, flowers, with broad subcordate petals overlapping each other, and in the larger fruits. From *Pyrus (Malus) Zumi, Matsumura,* which is also closely related to *Malus Toringo, Malus Sargenti* may be distinguished by the broader, often lobed leaves, the shape of the petals, the glabrous calyx-tube and the habit."

This species appears as the female parent in thirteen crosses attempted with pollen of eight varieties. The 290 pollinations matured

FIG. 88.—FRUITING BRANCH OF *M. sargenti* (843) ONE-SIXTH NATURAL SIZE, PHOTOGRAPHED OCTOBER 18

The fruits are a uniform dark red, becoming very dark, almost black, in late fall. After frosts the fruits become very soft, and then dissolve and disappear, leaving the pedicels upon the tree.

120 fruits representing 41.37 percent of the pollinations. Two crosses, those by Stayman Winesap and Fanny, failed in fruit production. Nine of the remaining crosses, altho maturing fruits from 52.27 percent of the pollinations, failed; seven because of failure of seeds to germinate and two because seedlings had no vitality and died immediately after appearance. Thus only two crosses have representation in

[1]Sargent, C. S. Trees and Shrubs 1, 71. 1905.

orchard: (1) The cross by Grimes in greenhouse in 1914, in which 15 pollinations matured 10 fruits containing 21 seeds, 12 of which germinated. Five seedlings were transferred to nursery and one is now living in its tenth year; this tree is 5 feet high, spreads 8 feet, has a diameter of 2.1 inches, and grades as "good." (2) The cross by Yellow Transparent in greenhouse in 1917, in which 31 pollinations matured 18 fruits containing 43 seeds, 2 of which germinated; one seedling is living in its seventh year, is 2 feet 8 inches high, spreads 3 feet 2 inches, has a diameter of 1.2 inches, and grades as "fair." Results do not encourage further use of this species as a female parent. As the pollen parent, *M. sargenti* was used in four crosses; three, on Stayman Winesap, Jonathan, and Lady with 20 pollinations failed. A cross on *M. siberica* (19643) in greenhouse in 1914, from 13 pollinations matured 8 fruits containing 48 seeds, 6 of which germinated; three seedlings went to nursery and two are now living in their tenth year; they average 7 feet 10 inches in height, 10 feet 10 inches in spread, and 2.9 inches in diameter and grade as "good."

37. *Malus scheideckeri* (19646)

Scions received from the Arnold Arboretum thru the U. S. Department of Agriculture, January, 1907, under the accession number 19646, which number has been retained. This is probably a hybrid altho there appears to be uncertainty as to the species combined. The Department of Agriculture list accompanying the scions follows the name *scheideckeri* with this remark: "A very fine seminal form of the double *M. spectabilis.*" Records at the Arnold Arboretum state that the plant was received from a German nursery in 1889 as *Pyrus spectabilis* X *floribunda scheideckeri.* Later it was renamed *Malus scheideckeri.* On herbarium mounts expression is given to the opinion that the plant is a hybrid between *Malus floribunda* and *Malus prunifolia.* The London Journal of Horticulture states,[1] "*Pyrus Scheideckeri* is a supposed hybrid between *spectabilis* and *Toringo* and is closely allied to *floribunda* and *baccata.*" Alliance to *Malus spectabilis* is suggested by a more or less marked tendency to multiplication of floral parts; to *toringo* or to *floribunda* by the large number of fruits having deciduous calyx lobes; and to *prunifolia* by the fact that many fruits have a regularly persistent calyx. Definite information regarding origin of this form does not appear to be available, and the names applied must be taken as expressions of judgment on the part of those who use the names in question.

This species is represented in the Station collection by one tree grown from root-graft made March 23, 1907. This tree at seventeen

[1]Journal of Horticulture and Home Farmer 55, 34. 1907.

years of age is 15 feet high, has a spread of 11 feet 3 inches, and a trunk diameter of 5.1 inches. Scions from this tree have been used for further propagation to increase the representation of the species and five trees grafted in 1914 average, in their tenth year, 12 feet 2 inches in height, 9 feet in spread, and 3.76 inches in diameter. There are also three trees on dwarf stocks in greenhouse, one grafted on Doucin in 1910 and two on paradise, one from graft of 1913, the other from graft of 1918. The tree grafted in 1907 began flowering in 1911 and has for several years given abundant bloom each year. The dwarfs in greenhouse bloom abundantly and have been freely used in crossing. In habit the tree is erect, as is shown in Fig. 89. The trunk and larger branches have smooth, light brown bark and the twigs are reddish-brown. The lenticels are numerous and conspicuous.

FIG. 89.—DORMANT TREE OF *M. scheideckeri* (19646)

This tree, which was grown from root-graft of March 23, 1907, was photographed during the dormant season of 1913-1914. It is erect in habit, and has bloomed abundantly each year since 1911.

Leaves.—Various, on spurs and flowering shoots they are elliptical, oblong or lanceolate; on terminal non-flowering shoots larger and broader, ovate or oblong; they are from 2½ to 4½ inches long and 1 to 2 inches wide, acuminate, mostly irregularly sharply serrate, scantily pubescent on both sides when young, becoming glabrous above; petioles rather slender, pubescent. Stipules lanceolate, acuminate, serrate, petioled, retained by a considerable portion of the leaves.

Flowers.—Produced in profusion from terminal and lateral buds on terminal shoots and to some extent from terminal buds of spurs on central and lower branches. The number of flowers in each cluster is extremely variable: for 196 clusters examined, the distribution was:

Number of flowers to cluster.....	2	3	4	5	6	7	8	9	10	
Number of clusters with flowers as above...	1	8	6	20	44	71	40	4	2	= 196

Flowers expand 30 to 35 mm. Pedicels slender, 30 mm. long, pubescent. Calyx lobes 5, triangular, acute, pubescent both sides, tips

reflexed in open flowers. Petals variable in number, size and form. In flowers having the normal number of petals they are 20 mm. long and 11 mm. wide; in flowers in which there is some multiplication they are somewhat smaller. Commonly they are elliptical, but frequently oblong or obovate. In one lot of 45 flowers examined the range in number was from 5 to 14 with an average of 9; in another lot of 112 flowers the range was from 4 to 9 with 68 percent having the normal number of 5 and an average for the lot of 5½. Young buds are globular, deep red, becoming considerably elongated before opening. Where the petals are increased in number, it is only those of the outer whorl that are colored and these fade to nearly white when fully expanded. Development and expansion of petals usually proceeds slowly and it is frequently the case that styles protrude from the apex of unopened buds one to three days in advance of anthesis; this feature is especially apparent on trees forced under glass, but also occurs in the orchard, at least in some seasons. The protruded stigmas are receptive and as this occurs well in advance of dehiscence of anthers, the flowers are markedly protogynous. Petaloid stamens are quite common; over 60 percent of the flowers examined had them in numbers from 1 to 7. Stamens with anthers are numerous, ranging for the 112 flowers examined from 24 to 44 with an average of 35.3; filaments slender, 4 to 10 mm. long, anthers plump, of long form, light yellow. Styles range in number from 4 to 11 with an average of 7, slender, 8 to 10 mm. long, connate ¼ the length, glabrous at base, but with a few hairs in a ring about the point of separation. Where the number of styles is high, usually a portion of them are small, very slender, and probably unable to function. Stigmas oval or orbicular, oblique. Fig. 90 from photograph of a twig with young buds, taken in the greenhouse March 9, 1914, shows length of pedicels and relative size

FIG. 90.—BRANCH OF *M. scheideckeri* (19646) FROM TREE IN GREENHOUSE IN BUD MARCH 9

Development of buds of this species is usually rather slow, and frequently styles protrude from the apex of unopened buds one to three days before full bloom. The branch illustrated here shows the length of pedicels and relative size of leaves and buds at this stage. The protruded stigmas are receptive, but since they occur before the dehiscence of anthers, the flowers are protogynous to a marked degree.

of leaves and buds at this stage of development; some of the buds have the protruding stigmas referred to altho rather indistinctly shown. Fig. 91 is from a photograph of a branch from the tree in orchard, taken April 30, 1915, and serves to illustrate the massing of color due to the close proximity of the bud clusters and also shows how completely the foliage is obscured by the open flowers.

Fruit.—Oblate, regular at base, somewhat ribbed at apex, irregularly ribbed in cross section; sides commonly unequal, color light

FIG. 91.—BRANCH OF *M. scheideckeri* (19646) IN FLOWER, APRIL 30

Young buds are deep red, fading to nearly white when fully expanded. Bud clusters are in close proximity, and the foliage is often almost completely obscured by the open flowers.

orange, no bloom. Skin smooth, thin, tough; dots few, small, irregular, russet, inconspicuous. Cavity shallow, broad, obtuse, regular; stem long, 30 to 40 mm., stout, oblique, russet, slightly pubescent; basin shallow, broad, irregular, ribbed. Calyx lobes in part deciduous, in part persistent; of 878 fruits recorded, 331 or 37.7 percent had deciduous calyx lobes and 547 or 62.3 percent had persistent lobes. Core large, cordate, oblate, distant, open; cells axile; carpels roundish-ovate, entire, glabrous, moderately concave. Seeds plump, of short thick form, medium in size, medium brown. Flesh greenish or yellowish according to degree of maturity, firm, crisp, juicy, but becoming somewhat dry in overripe fruits, acid. A fruiting branch with leaves mostly removed is shown in Fig. 92 from photograph taken September 16, 1915. A further illustration to show the concentration of fruit on terminal twigs within small areas, a feature quite characteristic of the species, is given in Fig. 93 from photograph taken October 18, 1916.

The species is attractive when in flower, but its appearance in early fall does not commend it because of a tendency to early loss of both foliage and fruit.

M. scheideckeri has been used as the female parent in 19 crosses with 12 varieties and one crab as pollen parents. Four of the crosses failed and 15 are now represented by 154 seedlings in orchard that range in age from 7 to 11 years. The total of pollinations was 1,096; fruits matured 260, or pollinations 23.72 percent successful. Seed content was low, averaging only 2.16 to each fruit; about 44 percent of the seeds germinated. Many seedlings were very weak and over 60 percent have died. Pollen from *M. scheideckeri* was used on four varieties, but no seedlings were produced; three of the crosses matured no fruits and while the other had fruits the seeds did not germinate. A low degree of success has attended the use of this species in breeding.

FIG. 92.—BRANCH OF *M. scheideckeri* (19646) IN FRUIT, SEPTEMBER 16

This species is attractive in flower but tends to lose foliage and fruit early.

38. *Malus siberica frutico coccinea* (19643)

Represented by one tree, worked in 1910, on potted Doucin stock which has flowered and fruited abundantly every year since 1913, and three trees from root-grafts of 1912. These trees, in the thirteenth year, average 13 feet in height, 12 feet in spread, and 4 inches in trunk diameter. In the early years erect, becoming ascending and finally somewhat spreading. The bark of the larger branches is light yellowish-brown; of twigs a still lighter brown with a reddish tinge.

Leaves.—When young covered with a fine close tomentum which is more dense below than above; mature leaves are 2½ to 4½ inches long and 1 to 2 inches wide, elliptical, oblong or ovate, or some of the smaller lanceolate; irregularly doubly dentate, acute, or

acuminate, glabrous thruout, dull dark green above, light green or grayish below, smooth and rather thin. Petioles slender, 1 to 1½ inches long, glabrous; stipules small, lanceolate, entire or serrate, petioled, mostly caducous.

Flowers.—Borne from terminal and lateral buds of shoots of the preceding year and to some extent from terminal buds of short spurs from older wood. Numbers of flowers to each cluster range, for 167 clusters examined, from 3 to 9, with 112 or 67 percent of the clusters

FIG. 93.—BRANCH OF *M. scheideckeri* (19646) SHOWING MASSING OF FRUIT WITHIN SMALL AREAS, PHOTOGRAPHED OCTOBER 18

having 6 flowers each. Buds globular when young, becoming elongated as they approach opening. Pink, fading to light pink, and finally to pure white in the open flower. Flowers expand 35 to 40 mm. Pedicels slender, 23 to 28 mm. long, pubescent, green. Ovary pubescent, tinged purplish-red. Calyx lobes 5, narrowly long-triangular, acuminate, pubescent both sides, 5 mm. long, 1.5 mm. wide at base. Petals 5, uniform, ovate, truncate at tips, abruptly contracted at base, 17 to 19 mm. long, 9 to 13 mm. wide, with claw, 2 mm. long. Stamens vary from 18 to 20, filaments slender, 4 to 10 mm. long, anthers plump, light yellow. Styles 5, slender, 9 to 12 mm. long, connate ⅓ the length, hairy only in a narrow band about the point of separation; tips of styles somewhat flattened, stigmas oval, capitate. The flowers are very fragrant. Fig. 94 shows a flowering twig of a dwarf tree as photographed in the greenhouse March 12, 1913.

Fruit.—Roundish oblate, average weight and measurements as determined from 83 fruits are as follows: weight 4.06 grams, longitudinal diameter 16 mm., transverse diameter 20 mm., regular at base, apex more or less irregular, cross-section somewhat ribbed, ground color yellow, blushed with shades of red from light to medium; fre-

FIG. 94.—TWIG OF *M. siberica frutico coccinea* (19643) IN FLOWER, MARCH 12. FIG. 95.—TWIG IN FRUIT, SEPTEMBER 2

The flowering twig shown here is from a dwarf tree in the greenhouse. When in fruit, this species closely resembles *M. baccata maxima* (810); the two are so alike in all essential characters that they are thought to be identical.

quently the red spreads over the entire fruit; bloom scant, waxy, white; skin smooth, polished, thin, tough; dots many, of medium size, russet, conspicuous. Cavity deep, rather broad, acute, regular; stem medium in length, 18 to 28 mm., stout, clavate, erect, green, glabrous. Calyx lobes deciduous in all fruits. Core small, oblate, nearly sessile, closed; cells axile, uniform; carpels obovate, entire, glabrous. Seeds

plump, of medium size, dark brown; flesh yellowish, firm, rather dry, acid. A small twig in fruit, from a top-graft, as photographed September 2, 1915, is shown in Fig. 95. There is only one other form of Malus in the collection that closely resembles this and that is No. 810, *M. baccata maxima*; indeed, the resemblance is so close in all essential characters that the two are thought to be identical.

Used as female in eighteen crosses, one of which, by Oliver, failed. The seventeen crosses maturing fruits had eight varieties and four crabs as pollen parents. Total pollinations 680; fruits 193 or 28.38 percent of the pollinations successful. Seed content averaged 6.7 to each fruit and 64.76 percent of the seeds germinated. The seventeen crosses are represented by 536 seedlings in orchard which range in age from six to eleven years. Performance of this form of Malus when used as female parent may be rated as good. As the pollen parent a much lower degree of success was attained. Pollen was used on thirteen varieties and two crabs in sixteen crosses with 438 pollinations which matured 42 fruits in five crosses; eleven crosses failed. The 42 fruits had the high seed average of 7.71 to each fruit and 65.43 percent of the seeds germinated. There are now in orchard 89 seedlings representing progeny of these five crosses.

39. *Malus soulardi* (Bailey) Britton (846,19665)

Pyrus soulardi Bailey, L. H. Amer. Gard. 12, 472. 1891.
Malus soulardi Britton and Brown. Illus. Fl. 2, 235. 1897.
Pyrus ioensis X *Pyrus malus* Bailey, L. H. Evolution of Our Native Fruits, 189. 1898.

Scions received from the U. S. Department of Agriculture in January, 1907, under the number 19665, and a second lot direct from the Arnold Arboretum in January, 1908, which was carried as 846. The representation includes grafts on paradise and Doucin stocks in the greenhouse, and root- and top-grafts in the orchard from both lots. An average root-graft of 1908 measures 21 feet high, 20 feet 9 inches spread, and 7.3 inches trunk diameter. Trees vigorous, of symmetrical, somewhat spreading habit; bark of the trunks of young trees dark gray, in older trees becoming rough; the outer layers break up into more or less irregular longitudinal ridges and assume a dark, brownish-black color. Branches are dark gray; twigs a dark chocolate-brown, or on vigorous non-flowering twigs a deep reddish-brown. Young twigs are covered with a close, dense pubescence which persists until late fall, but mostly disappears during the first winter. Scions inserted on Virginia Crab March 25, 1911, appeared as in Fig. 96 when photographed October 25 of the same year.

Leaves.—Large, thick, mostly ovate and cordate, but sometimes rounded at base, oblong, oval or even obovate, 3 to 5 inches long, 1½

to 3 inches wide, irregularly crenate-dentate, often distinctly 3-lobed, sometimes variously notched towards the apex which is usually obtusely rounded, but occasionally acute in oblong leaves; extremely rugose, so marked is this character that the leaves are not to be mistaken for those of any other Malus in the collection, pubescent above and densely white tomentose below when young, becoming glabrous above but retaining the white tomentum thru the season; very dark green above, white below. Petioles stout, ½ to 1½ inches long, persistently pubescent; stipules minute, linear, caducous. In examining leaves of this species October 29, 1914, it was noted that the leaves were dark green, showing no effects of frost, while leaves on trees of most other species were crisp, brittle, and discolored from freezing.

FIG. 96.—TOP-WORKED TREE OF *M. soulardi* (846)

Scions inserted on Virginia Crab March 25, 1911, and photographed October 25 of the same year.

Flowers.—Flower clusters appear from the terminal and lateral buds on terminal shoots and from terminal buds of short spurs. On most terminal shoots only the terminal buds produce flowers, but on some there are a few clusters from lateral buds, mostly near the ends of the shoots. Flower buds are of medium size, globular or oval, deep pink, becoming much lighter as they approach anthesis; open flowers expand from 30 to 35 mm. and are only slightly tinged with pink. Of 25 clusters examined 3 had 4 buds each, 15 had 5 each, 6 had 6 each, and one had 7. Pedicels are short and stout, 15 to 17 mm. in length, heavily pubescent as is also the ovary. Calyx lobes 5, short triangular, acute, pubescent both sides. Petals 5, almost orbicular, deeply cordate at base, 15 mm. long, 14 mm. wide, with claw 2 mm. in length; the petals are imbricated to the base, presenting an unbroken ring about the essential organs, giving the flower an appear-

ance in strong contrast with the very open flower of *M. ioensis*. Stamens 14 to 21 averaging about 20, filaments slender, 5 to 8 mm. long; anthers plump, light yellow. Styles 5, stout, 11 mm. long, connate ⅓ the length, hairy from base nearly to the top. Stigmas oval, terminal.

FIG. 97.—BUD CLUSTER OF *M. soulardi* (846), MARCH 15

The petals lap over each other at the base, forming an unbroken ring about the essential organs. This gives the flower an appearance which contrasts decidedly with the very open flower of *M. ioensis*.

A bud cluster of this species as photographed in the greenhouse March 15, 1916, is shown in Fig. 97.

Fruit.—Large size for a crab, but extremely variable on old trees, larger and more uniform on young trees; one of the trees from root-grafts made in 1908 bore a fruit in 1914 that weighed 75 grams, had a vertical diameter of 45 mm., and a transverse diameter of 60 mm. The average of 425 fruits from a tree twenty years old weighed 38.27 grams, had a vertical diameter of 34 mm., and a transverse diameter of 41 mm. The extreme range in weight for the 425 fruits was from 15 grams for the smallest to 63 grams for the largest. Form oblate, usually regular at base, but quite irregular at apex and the cross-section is usually more or less ribbed; sides often unequal; color green, sometimes becoming yellowish in the sun, and finally pale yellow when thoroly ripened. Skin smooth, extremely unctuous, of medium thick-

ness, tough; dots numerous, small, regular, dark green, inconspicuous. Cavity shallow, narrow, obtuse, often somewhat irregular or slightly lipped; stem stout, 22 to 26 mm. in length, clavate, oblique, green, pubescent; calyx of medium size, densely pubescent, closed. Basin shallow to medium in depth, obtuse, irregular, ribbed; calyx lobes of medium size, short and broad, obtuse, inflexed; calyx tube long, large, cylindrical, with a stout projecting pistil point. Core small, round, median, closed. Stamens marginal, core lines clasping; carpels roundish, emarginate, glabrous, moderately concave.

Seeds plump, of medium size, acutely pointed, dark brown. Flesh white, firm, crisp, juicy, very acid, inedible in the raw state. The fruit possesses a distinct quince-like odor quite similar to that of fruit of *M. ioensis*. The 425 fruits examined have an average seed production of 3.18; this is considerably below the average of 4.22 for the crab group and places the species 7th from the bottom of the list of 25 species and varieties examined. At the left of Fig. 98 is shown a fruit of *M. soulardi* for contrast with the Hyslop Crab, center, and 833 *M. malus fl. pl.* on the right, all natural size.

In 1891 this crab was described by Professor Bailey as *Pyrus soulardi*, a new species.[1] Later Professor Bailey[2] expressed the belief that the Soulardi crab was a hybrid between *Malus ioensis* and the common apple.

The crab was first propagated and disseminated by J. G. Soulard of Galena, Illinois. Mr. Soulard's statement places the origin of the tree as from a crab thicket a few miles out of St. Louis. In the years following its introduction many statements favorable and unfavorable were made with regard to its qualities, but the fact that over fifty years have elapsed since its introduction without giving this crab standing among desirable kinds indicates general belief in its worthlessness. As a means of throwing light upon its supposed hybrid character it is desirable that seedlings from self-fertilized seed be grown to fruiting, but the possibility of accomplishing this seems remote because all efforts thus far made to self-fertilize the flowers have failed. *M. soulardi* has been used as the female parent in 26 crosses; 16 crosses failed and 10 matured 52 fruits; of the 575 pollinations only 9 percent were successful. The seed average was 2.32 to each fruit; this falls below the average found for 425 open-pollinated fruits, which was 3.18 to each fruit. From the 52 fruits there were 121 seeds, 67 or 55.45 percent of which germinated. Fifty-four seedlings from 7 crosses were planted in nursery, but only 13 from 4 crosses are living in the seventh and eighth years. *M. soulardi* was used as the male parent in 3 crosses, but all failed.

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[1]Bailey, L. H. Amer. Gard. 12, 472. 1891.
[2]Bailey, L. H. Evolution of Our Native Fruits. 1898.

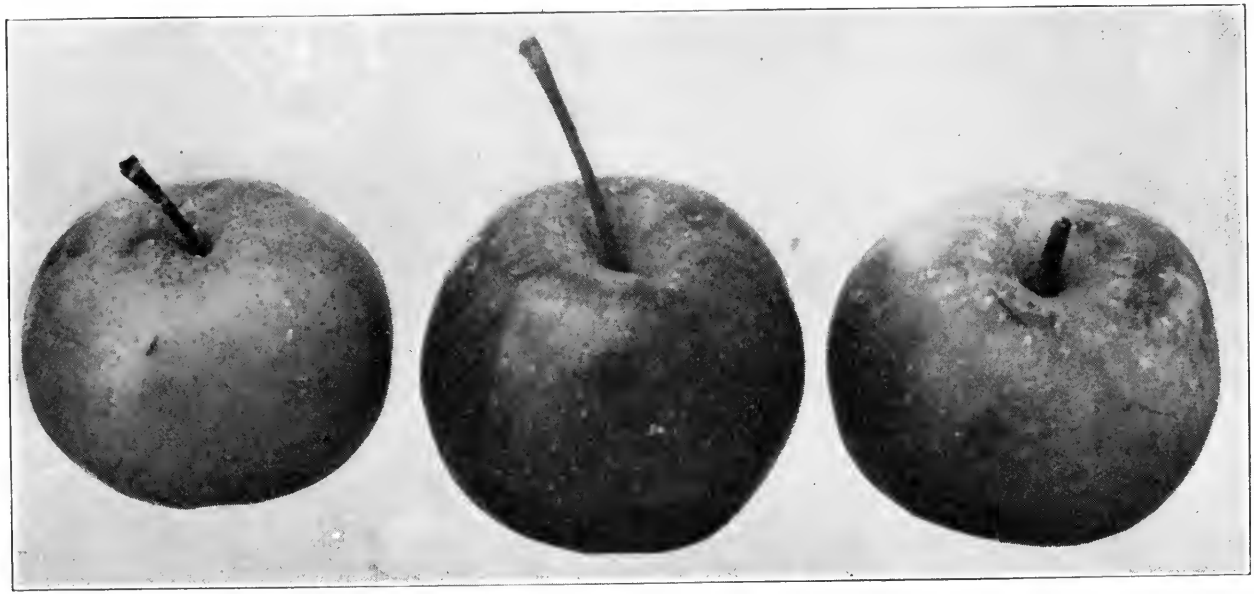

FIG. 98.—THREE OF THE CRAB FORMS OF MALUS PHOTOGRAPHED SEPTEMBER 20, 1916

Left to right: *M. soulardi* (846), *Malus* Hyslop Crab (824), *M. malus fl. pl.* (833). *M. soulardi* was introduced more than fifty years ago, and still has no standing among desirable species. There seems to be a general belief that it is worthless.

Self-pollinations were attempted on 193 flowers in six different years, but no fruits matured. The species is apparently self-sterile; it fails entirely as a male parent and, as a female parent, gives so low a percentage of successful pollinations, has such low seed content, and produces seedlings so lacking in vitality, that it can only be regarded as worthless for breeding purposes.

FIG. 99.—TREE OF *M. spectabilis* (848)

Top-worked on Virginia Crab in 1908 and photographed October 25, 1911. The habit of this form of *M. spectabilis* seems to be upright, with a tendency to spread above as the tree gets older.

40. *Malus spectabilis* Ait. Hort. Kew. 2, 175. 1810

This species is believed to have come from China. It is known only in the cultivated condition and appears under various forms, some of which have been given varietal names. Flower colors are variously stated to be flesh-colored, dark red, rose-red, pink, and pink and white. It is frequently mentioned by horticultural writers and has been highly commended for its beauty. Scions of two forms of *Malus spectabilis* were received from the Arnold Arboretum in 1908 and appear in the Station list as Nos. 848 and 849.

Malus spectabilis var. 1615 (848)

This form was propagated by both root- and top-grafts. It is now represented in the collection by two trees root-grafted in 1912 and by one tree top-worked on Grimes in the same year. The best of the two root-grafted trees is now 10 feet high, has a spread of 7 feet, and a diameter of 3.1 inches. The top-worked tree is of about the same size and has formed a symmetrical crown. This form, top-worked on Virginia Crab in 1908 and photographed October 25, 1911, is shown in Fig. 99.

The habit of this form of *M. spectabilis* appears to be upright with a tendency to spread above as the tree gets older. Bark of large branches is bright reddish-brown, the twigs a darker shade.

Leaves.—Oblong-ovate or elliptical, occasionally obovate and some smaller leaves approaching lanceolate; mostly obtusely tapered at base, apex acute; finely crenate, or crenate below and obtusely serrate above, slightly pubescent when young, becoming glabrous thruout, 2 to 4½ inches long, ¾ inch to 1¾ inches wide, thin and delicate when young, becoming thicker and somewhat coriaceous at maturity.

Flowers.—Produced from terminal and lateral buds of shoots of the preceding year and from terminal buds of short spurs. Buds globular, pink, appearing much like those of varieties of *M. malus;* flower expands 47 mm., pedicels rather stout, varying in length from 17 to 30 mm., pubescent, ovary heavily pubescent. Calyx lobes 5, thick, broadly triangular, acute, 7 mm. long, 5 mm. wide at base, reflexed in open flowers, pubescent both sides. Petals oval, 18 mm. long, 15 mm. wide, with claw 4 mm. long, somewhat tinged with pink. Stamens 18 to 20, filaments slender, 9 mm. long; anthers plump, light yellow. Styles 5, slender, 11 mm. long, connate from base up for 3 to 4 mm., hairy from base to above the point of separation; stigmas oval, capitate, convex.

Fruit.—Oblate, more or less irregular at base and apex, in cross-section ribbed, sides unequal, yellow, more or less blushed with light red; skin smooth, thin, tough; dots many, small, round, white, inconspicuous; cavity shallow, of medium width, obtuse, irregular; stem of medium length, 20 to 25 mm. long, slender, erect, green, often tinged with red, glabrous. As to size, the fruits of this variety fall into the group of crabs having fruits of medium size. Weight as averaged from 100 fruits is 4.32 grams. The average longitudinal diameter is 18 mm., the average transverse diameter 22 mm. Calyx lobes are mostly persistent; of the 100 fruits examined the lobes were persistent, with more or less fleshy bases, in 91 and deciduous in 9. Basin shallow or often none, narrow, obtuse, irregular, ribbed. Core, when normal, of medium size, oblate, median, closed: commonly the core is not normal, but has a complete, or more often partial secondary whorl of carpels superposed upon the normal whorl; carpels of the lower whorl vary from 5 to 8, in the superposed whorl there may be from 1 to 6. The 100 fruits examined had numbers of carpels as follows:

With 5 carpels	13
With 6 carpels	51
With 7 carpels	25
With 8 carpels	8
With 9 carpels	1
With 11 carpels	1
With 12 carpels	1

The carpels of the superposed whorl are responsible for the irregularities observed in many fruits; in some cases development of seeds in one or two of the superposed carpels causes a protuberance which forces the calyx far over to one side, giving the appearance as shown in the central fruit in Fig. 73, page 541. Cells are commonly abaxile; carpels ovate, emarginate, glabrous; stamens marginal, core lines

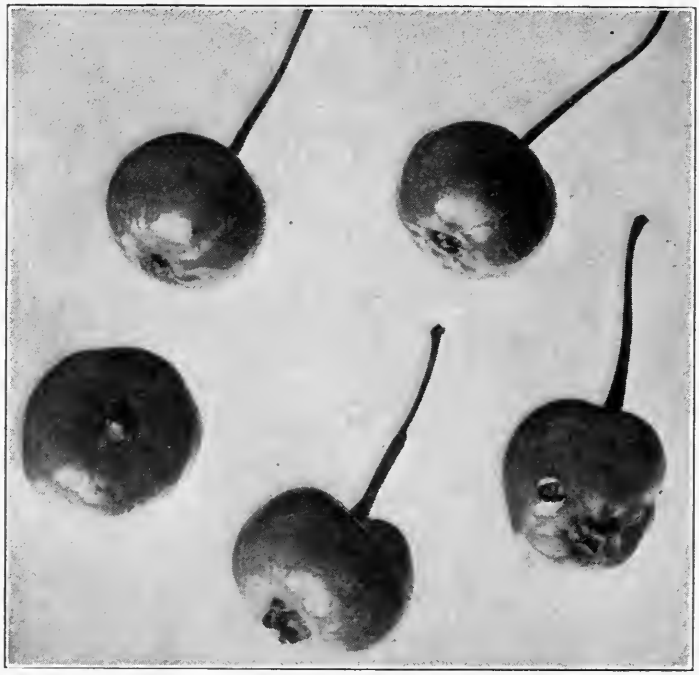

FIG. 100.—FRUITS OF *M. spectabilis* (848), Natural Size, SEPTEMBER 11

Due to the additions made by the superposed carpels, this species has an average seed production of 5.31 for 100 fruits, which is considerably above the average for the crab group.

clasping; seeds plump, of medium size, medium brown; the average seed production for the 100 fruits is 5.31, which is considerably above the average for the crab group. This higher seed production is due to the additions made by the superposed carpels, for these produce as good seeds and with almost as much regularity as do the carpels of the normal whorl. Flesh yellowish, firm, crisp, juicy, acid. A group of average fruits of this variety, photographed September 11, 1916, appear in Fig. 100.

41. *Malus spectabilis* var. 458/4 (849)

This form is now represented only by a graft on potted paradise made in 1910. It flowered and was used in breeding in each of the years 1913, 1914, 1916, and 1917. Its appearance as photographed June 21, 1916, when carrying 8 hand-pollinated fruits, is shown in Fig. 101. Bark of the stem grayish-brown, of the twigs reddish-brown, smooth, habit of growth erect.

Leaves.—Ovate to elliptical, in general somewhat larger than are the leaves of No. 848, previously described; serrate, acuminate, or acute, slightly pubescent, becoming glabrous.

Flowers.—Produced from terminal and lateral buds of terminal shoots and from terminal buds of rather numerous short spurs, 2 to 17 flowers to the cluster; distribution in 30 clusters examined was as follows:

Buds to the cluster	2	3	4	5	6	7
Number of clusters	1	5	5	11	6	2

Buds globular, pink; pedicels rather stout, 22 to 33 mm. long, pubescent, green. A bud cluster as photographed in greenhouse February 24, 1917, is shown in Fig. 102. Flower expands about 30 mm., calyx short triangular, 3 mm. wide at base, acute. Petals often nearly orbicular, sometimes obovate, variable in form and number; 38 flowers examined have petals in numbers as follows: 12 have 15 petals each, 5 have 18 each, 6 have 19 each, 3 have 20 each, 4 have 21 each, and the following numbers of petals are represented by one flower each, 14, 16, 17, 22, 23, 25, 26, and 28. Stamens vary greatly in numbers and in length of filaments, the longest filament found is 6 mm. in length; from this they range to less than 1 mm., some anthers are practically sessile; numbers of stamens with anthers in 38 flowers for which there are records are as follows:

Number of stamens	25 to 30	31 to 35	36 to 40	41 to 45	46 to 50	51 to 55	56 to 60
Number of flowers	5	3	6	7	11	3	3

In one flower, in addition to 40 stamens with anthers are 5 petaloid stamens; these occur in most other flowers in numbers from 1 to 4. Styles slender, about 12 mm. long, usually much contorted and nearly as variable in numbers as are the stamens; for the 38 flowers of record, distribution of numbers of styles is as below:

Number of styles	4	5	6	7	8	9	11	12	13	14	15	17	18	22	24	30	35
Number of flowers	1	1	1	6	7	6	1	1	2	2	2	3	1	1	1	1	1

The styles are free to the base and are hairy from the base up for half the length; stigmas are small and most of them, as judged from appearance, are incapable of performing proper functions.

FIG. 101.—DWARF TREE OF *M. spectabilis* (849) IN GREENHOUSE

This form, which was grafted on paradise in 1910, was photographed June 21, 1916, when carrying 8 hand-pollinated fruits.

Fruit.—Oblate, regular at base and apex, somewhat ribbed in transverse section, yellow blushed with light red, of medium crab-size. Sixteen fruits weighed and measured average 8.09 grams in weight, 23 mm. in longitudinal diameter, and 27 mm. in transverse diameter. Skin smooth, thin, tough; dots few, small, regular, round, white, inconspicuous; cavity shallow, medium in width, obtuse, regular; stem slender, variable in length, 25 to 40 mm. long, erect, green, slightly pubescent; calyx open, lobes glabrous outside, pubescent within. Basins very shallow, medium in width, obtuse, irregular, ribbed. Calyx lobes deciduous in some fruits, persistent in others; of 17 fruits recorded 10 had lobes deciduous, 6 had persistent lobes, and 1 retained 2 lobes with fleshy bases while 3 lobes were regularly deciduous. Core oblate, of large diameter due to the intrusion of cells above the normal number. Sixteen fruits of record as to cells have distribution as follows; 2 have 6 cells each, 7 have 7 each, 4 have 8 each, 3 have 9 each; these supernumerary cells are all crowded into 1 whorl and not, as in the other variety of *spectabilis,* into 2 whorls, one superposed upon the other. Seeds plump, of medium size, dark brown. Flesh yellowish, tender, crisp, juicy, becoming dry and mealy when overripe, subacid. Three fruits, one with persistent calyx lobes and one showing the scar of deciduous lobes, are represented natural size as photographed June 29, 1916, in Fig. 103. Multiplication of parts of the flowers in this variety appears to be due to the growth of adventitious whorls of petals and stamens, and not wholly or even in any considerable part to transformation of one organ into another. That there may

be some transformation of stamens into petals is indicated by the presence of petaloid stamens in most flowers, but where transformation is an important factor in the multiplication of petals, there is, usually, a corresponding diminution in numbers of stamens. In this plant the stamens, instead of being diminished in number by multiplication of petals, are increased in numbers to almost as great an extent as are the petals. Not only are petals and stamens involved in the multiplication,

FIG. 102.—BUD CLUSTER FROM TREE OF *M. spectabilis* (849) IN GREENHOUSE, FEBRUARY 24

but the styles also have increased far beyond the expected numbers. Normally each style of an apple flower represents a carpel, but in a number of flowers examined the styles far exceed the carpels in numbers. Flowers having 5, 7, or 8 styles have corresponding numbers of carpels, but in those flowers with from 13 to 35 styles no accompanying carpels are apparent; they are either so little developed as to be undiscoverable by ordinary means of macroscopic examination, or they do not exist and, in that case, the reasonable explanation seems to be that the styles of discovered carpels have increased by branching. If branching has occurred it takes place below the apparent base from which the perfectly free styles spring. The contorted, slender, and weak appearance of the styles in this variety suggest probable sterility, but pollinations made have yielded some fruits, demonstrating that the variety is not wholly sterile. For the four seasons in which the variety has flowered 114 flowers have been pollinated with pollen

from twelve other varieties. Seventeen fruits were developed; this is 14.91 percent of the flowers pollinated, but one of the fruits proved to be parthenocarpic, leaving 16 fruits that produced apparently good seeds; this represents as high a percentage of successful pollinations as

FIG. 103.—FRUITS OF *M. spectabilis* (849), NATURAL SIZE, JUNE 29

The bottom fruit shows persistent calyx lobes, and the one at the left the scar of deciduous lobes.

has been obtained, in some cases, from species or varieties having perfectly normal flowers. The 16 fruits produced seeds in numbers from 2 to 16 and the total reached 113 or an average of 7 seeds to each fruit, nearly double the average for all of the crab group included in the Station records. From 26 seeds of fruits of 1914, seven trees now in their tenth year, which were planted in orchard in the spring of 1917, have been grown; of the 87 seeds from fruits of 1916, 26, or nearly 30 percent, germinated and 15 of the seedlings were living in the autumn of 1923.

This variety of *spectabilis* is an interesting form of Malus and further studies of modifications of its flowers and the behavior of flowers when pollinated will be made as opportunity offers.

42. *Malus sylvestris fastigiata bifera* (820)

Scions of this form were received in 1908 under the name *Malus fastigiata bifera,* and it has been carried as No. 820, under this name. The plant from which the scions were taken was received at the Arnold Arboretum in 1888 from L. Spath, Rexdorf, Berlin, Germany, as *Pyrus ringo fastigiata bifera.* Later the name was changed to *Pyrus malus fastigiata bifera,* and more recently to *Malus sylvestris fastigiata bifera.* Botanical works consulted do not mention the varietal name *fastigiata* as applied to the apple, but the specific name *sylvestris* was used by Tournefort[1] in 1700 and he cites its use by other and earlier writers. Some later botanists have used the name *sylvestris* to designate species under the genus Pyrus, others have used it as a varietal name for forms of the common apple. *Pyrus sylvestris* as used by European botanists is applied to the Smooth Wild Apple of Europe which they desire to separate from *Pyrus malus* or *Malus malus* because of its generally shorter and less pubescent leaves. The "Index Kewensis" does not recognize *sylvestris* as a species and most botanists agree that the plant called *sylvestris* is only one of several forms that are doubtfully distinct from the common apple. *Pyrus sylvestris* is recognized by Koch,[2] but he rates it as very near *Pyrus pumila,* often closely resembling *Pyrus prunifolia,* and suggests that it is only a wild form of the smooth-fruiting summer apple which came thru cultivation, from *Pyrus prunifolia.* All authorities agree that the forms of the wild European apples are very numerous and that to trace the genesis of any particular form is impossible because intermingling, which is very common within the genus, has been going on for so long a period that original types are obliterated. The course of descent of existing forms is unknown and, altho the extremes of variation are wide apart, characters that are distinctive and of sufficient stability to be acceptable as means of defining species are wanting. The form in hand, *Malus sylvestris fastigiata bifera,* is one of the European forms cultivated to some extent as an ornamental.

This species is represented by two trees from root-grafts of 1908 and one grafted in 1914. Also by two dwarf trees in greenhouse, one grafted on Doucin in 1910, and one on paradise in 1917. The grafts of 1908, now sixteen years old, average 12 feet in height, 8 feet in spread, and with trunk diameter of 3.8 inches. They flower regularly and usually abundantly.

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[1]Tournefort, J. P. Inst. Rei Herb. 1, 634. 1700.
[2]Koch, Karl. Dendrol. 1, 206. 1869.

The bark of the trunk and larger branches is bright, light yellowish-brown, and smooth except where slightly roughened by the numerous transversely elongated lenticels. Twigs are bright reddish-brown and as late as the middle of October still show traces of the fine white pubescence with which they are thickly covered in early spring.

Leaves.—Elliptical or some of the smaller ovate, 2 to 4½ inches long, ¾ to 1¾ inches wide, serrate, acute, or acuminate; petioles slender, ¾ to nearly 2 inches in length, pubescent, narrowly and deeply channelled. When young the leaves are densely covered below with fine white tomentum, scantily pubescent above, becoming glabrous, but retaining some of the tomentum below until late fall. In texture the leaves are comparable to those of many varieties of *M. malus*.

Flowers.—Produced from terminal and lateral buds on terminal shoots. Pedicels slender, in buds, very short so that bud clusters are obscured by leaves. As development proceeds the pedicels elongate, becoming nearly an inch in length; the bud axis also elongates somewhat, becoming from 7 to 12 mm. in length. The buds are thus projected outward so that when fully open, leaves are completely hidden and there is the appearance of a solid mass of flowers. The number of buds to the cluster varies from 2 to 9; the distribution in 98 clusters counted is as follows:

Number of buds	2	3	4	5	6	7	8	9
Number of clusters	1	6	15	25	36	11	2	2

Open flowers expand 38 to 40 mm. In bud the petals are deep reddish-pink, fading to nearly white in open flowers. Pedicels, ovary, and calyx lobes densely white tomentose. Calyx lobes 5, triangular acute, 5 mm. long by 2½ mm. wide at base, erect in bud, becoming reflexed in open flowers. Petals 20 mm. long, 12 mm. wide, oblong or oval with short claw. Stamens have slender filaments 5 to 9 mm. in length, and light yellow anthers. In number they vary extremely; thus the distribution for 39 flowers examined is as follows:

Number of stamens	5	6	7	8	9	10	12	16	17	18	19	20	22	
Number of flowers	1	1	2	7	5	4	2	2	3	8	1	2	1	= 39

Distribution of styles in these flowers is as follows:

With 3 styles	3
With 4 styles	18
With 5 styles	18

Styles are stout, 8 to 9 mm. in length, connate ⅓ the length and hairy from base to point of separation. The long terminal shoots each presenting a solid mass of color 6 to 20 inches in length make the tree extremely attractive at flowering time. A branch in flower is shown in Fig. 104.

Fruit.—Roundish-conical, maturing early in September. Diameter and weight as averaged from 421 apples are as follows; longitu-

dinal diameter 2.88 cm., transverse diameter 3 cm., weight 13.72 grams. A peculiarity of the fruit is the absence of depression at the basin end; the apex is conical, with the surface more or less abruptly rounded up to the bases of the somewhat thickened, persistent calyx lobes; base somewhat flattened, cavity medium in depth, rather broad, obtuse, regular; stem medium in length, 15 to 20 mm. long, slender, erect, pubescent. Color dull yellow, on some fruits a more or less well defined blush of pinkish-red. Dots few, small, gray, inconspicuous. Calyx lobes rather short, broad, acute, pubescent, reflexed; tube large, funnel-form. Core medium in size, cordate, median, closed or sometimes half-open; carpels ovate, glabrous, deeply concave, varying in number from 3 to 5. For the 421 fruits examined 32 had 3 carpels each, 108 had 4 each, and 281 had 5 each. Seeds average 5.37 to each fruit. They are inclined to be shrivelled somewhat, are of medium size, and of medium brown color. Flesh is yellowish, firm, dry, becoming mealy in overripe fruits; the flavor is mildly subacid. When ripe the skin cracks irregularly over the whole surface, giving a netted appearance to the fruit. A branch in fruit is shown in Fig. 105 from photograph taken August 22, 1917.

FIG. 104.—BRANCH OF *M. sylvestris fastigiata bifera* (820) IN FLOWER, APRIL 30

In this species, the pedicels and bud axis elongate as development proceeds, projecting the buds outward. When the flowers are fully open, they form a solid mass completely hiding the leaves.

This form of *sylvestris* was used as female in seventeen crosses by twelve varieties; four crosses failed to mature fruit and four failed because seeds did not germinate; nine crosses are represented in orchard by 213 seedlings from seven to twelve years old. The number of pollinations made was 491, from which 144 fruits matured, or 29.32 percent of the pollinations produced fruits. As the pollen parent the variety was used in seven crosses; four crosses failed and three matured 16 fruits; only 11.67 percent of the 137 pollinations were successful. The three crosses producing fruits are represented in orchard by 40 seedlings ten and twelve years old.

FIG. 105.—FRUITS OF *M. sylvestris fastigiata bifera* (820)
PHOTOGRAPHED AUGUST 22, 1917

These fruits are a dull yellow in color, with sometimes a more or less well-defined blush of pinkish-red. When the fruit is ripe, the skin cracks over the entire surface, giving it a netted appearance.

Whether used as male or female the progeny of this form of Malus is of reasonable vigor and the degree of success in crossing encourages further use in breeding.

43. *Malus sylvestris fl. pl.* (833)

This form was received as *Malus malus fl. pl.* and has been propagated under the number 833. The original plant in the Arnold Arboretum was received from a nursery more than thirty years ago as *Pyrus communis;* later the name was changed to *Malus malus fl. pl.* and finally to *Malus sylvestris fl. pl.* Of ten root-grafts made January 20, 1908, six survived and were planted in orchard in the spring of 1910. These trees have maintained a uniform growth, are fastigiate in form with average dimensions as follows; height 14 feet 9 inches; spread 12 feet; and trunk diameter of 5.4 inches. Bark of trunk and branches dark brown with a tinge of olive-green; twigs reddish chocolate-brown, pubescent when young, but becoming nearly glabrous in early fall.

Leaves.—One to 4 inches long, ½ to 2 inches wide. The larger leaves are few and confined to the outer ends of rapidly growing shoots. Leaves from lateral buds and spurs below are mostly small. Large leaves are roundish ovate, the smaller vary from orbicular to oblong and lanceolate, acuminate or acute, crenate-dentate or with blunt serrations toward the apex; densely clothed with close-matted tomentum below, and sparsely pubescent when young, becoming glabrous above; petioles stout, more or less red in color; stipules small, lanceolate, persisting on some leaves.

Flowers.—One of the trees in orchard produced a few flower clusters and a few fruits in 1915; in 1916 all of them flowered sparingly and, tho not heavily, some of the trees have flowered each year since. Flowers are borne from terminal and lateral buds of terminal shoots. Of 70 clusters counted, 1 had 4 buds, 10 had 5 each, 41 had 6 each, and 18 had 7 each. In bud the clusters are short and compact, pink, fading to white as flowers expand. Open flowers vary considerably in size; those measured range from 30 to 53 mm. Pedicels are rather stout, pubescent, 10 to 16 mm. long, ovary pubescent; calyx lobes triangular to lanceolate, acute, pubescent both sides, tips reflexed in open flowers. Petals nearly orbicular, abruptly contracted to the short claw, varying in number from 5 to 10, pure white when expanded. Petaloid stamens 2 to 5 of various forms. Stamens with anthers 27 to 34, filaments slender, 7 to 11 mm. long, anthers plump, light yellow, mostly with abundant pollen. Styles 6 to 9, slender, 11 mm. long, connate nearly half the length, hairy from base to above the point of separation; stigmas oval, oblique. Multiplication of petals is not so universal as might be inferred from the designation *flore pleno*; as many flowers have the normal 5 as have greater numbers and few possess a complete second whorl. The flowers, however, are large and usually the clusters are massed, conspicuous and very showy.

Fruit.—Distinctly oblate, with regular base, corrugated apex, and sides somewhat unequal. The average of 14 fruits gives the weight as 27 grams, longitudinal diameter 31 mm., and transverse diameter 40 mm. The ground color is yellow blushed and washed with an attractive red; bloom scanty, waxy, gray; skin smooth, thin, tender; dots few, small, round, white or russet, inconspicuous. Cavity shallow,

FIG. 106.—FRUITING BRANCH OF *M. sylvestris fl. pl.* (833), PHOTOGRAPHED OCTOBER 2

Apparently this variety succeeds better as a male parent than as a female parent. Seedlings from this species as a female parent are small and weak; when it is used as a male parent, the seedlings are more vigorous.

broad, obtuse; stem medium in length, rather stout, erect, smooth, calyx large, open. Basin shallow, broad, ribbed, calyx lobes long, slender, acute with reflexed tips; core of medium size, oblate, median, half open; carpels obovate, entire, tufted, moderately concave; seeds plump, of medium size, flesh yellowish, tender, moderately juicy, becoming somewhat mealy when over-ripe, sweet. A fruiting branch is shown in Fig. 106 and a single fruit appears at the right in Fig. 98, page 571.

M. sylvestris fl. pl. has been used as female in two crosses, one by Shockley in 1916 and one by Fanny in 1921. Pollinations by Shockley

were less than 5 percent successful, the seed average was 7 to each fruit and 53 percent of the seeds germinated; 54 percent of the seedlings are living in the eighth year, but the trees are small and deficient in vigor. For the Fanny cross, while 25 percent of the pollinations matured fruits, seed content of the fruits was low, only 20 percent germinated, and the seedlings were small and weak. Degree of success does not encourage further use of this plant as a female parent. As a male parent in four crosses, one cross failed and three yielded 33 fruits. Seed content was low, but germination was fair and the seedlings are more vigorous than were those of the other group. Apparently the variety succeeds better as the male parent.

44. *Malus sylvestris* (19631)

Scions received from the U. S. Department of Agriculture in January, 1907, under the number 19631, with this notation, "Sometimes called *M. acerba,* and by the older botanists was considered a form, at least, of the common apple." Success did not attend propagation with these scions. A few started growth but died before the end of the season. Scions received from the Arnold Arboretum in 1908 were successfully worked and the species is now represented by three trees from root-grafts of 1908 and by two dwarfs, one on paradise, the other on Doucin. These dwarfs have been forced in greenhouse for eleven years but only in one year (1918) were flowers produced, and these in very few clusters.

The trees in orchard, now seventeen years old, average 21 feet high, 19 feet in spread, and 8.4 inches in diameter. They are healthy and vigorous, but remarkably tardy in flower production. One tree in 1919 and again in 1920 bore a few scattered clusters, but none have appeared since.

Bark of trunk light olive-brown, of twigs light brown, but twigs are gray in appearance because of the close pubescence which persists thru the season.

Leaves.—Mostly broadly ovate 2½ to 3½ inches long, 1 to 2 inches wide, doubly serrate, or dentate, shortly acuminate, glabrous above, covered below with a dense, short pubescence which is persistent. Petioles ½ to 1 inch long, more or less pubescent.

Flowers.—The flowers as described from the greenhouse tree are borne in clusters of 6 on terminal buds of twigs. Expansion of flower 34 mm. Calyx lobes 5, narrowly triangular, acuminate, strongly reflexed, medium in size, pubescent. Buds are large, oval, with round apex, and color light pink. Pedicel is medium length, stout, pubescent, erect; ovary, pubescent; petals are 5 in number, oval to elliptical, with round apex; claw short and broad. Fourteen stamens measure 5 to 7 mm. long, filaments slender; anthers plump, medium size, light yel-

low. Styles 5, 10 mm. long, slender, connate for 3 mm. of their length, hairy at base, stigma is medium size, oval, oblique.

Fruit.—Roundish-oblate, with regular and rounded base, and regular apex, regular cross-section, and equal sides. Size small to medium; appears like a small apple; typical fruit weighs 42 grams. Color is self greenish-yellow or sometimes very faintly striped. Bloom is scant, waxy, white; skin smooth, tough, medium in thickness. Dots few, small, irregular, greenish, scattered, inconspicuous. Cavity shallow, medium broad, obtuse, regular, has short slender, erect, green, glabrous stem. Calyx persistent, small, pubescent, closed. Basin shallow, medium broad, obtuse, and regular. The calyx lobes are medium size, short and broad, acute, erect; calyx tube medium in length, medium size, and conical. Core medium size, cordate, oblate, median, half open. Stamens, marginal, core-lines clasping; cells slightly abaxile, uniform; carpels, obovate, emarginate, glabrous, concave. The seeds are plump, medium size, and dark. Axis medium length, erect; flesh is greenish, firm, crisp, juicy, acid, with crab-like flavor. The number of seeds is high; of 3 fruits, one has 10 perfect seeds and the other 2 have 9 each.

45. *Malus toringo* Carriere Rev. Hort., 210. 1872

Pyrus toringo sieboldi Cat. Rais. 1, 4. 1856. Koch, Dendrol., 212. 1869. Regel, Ind. Sem. Hort. Petrop., 51. 1858.
Pyrus sieboldi regel Gartenflora 8, 82. 1859.

Each of the two lots of Malus scions received, the one from the Arnold Arboretum thru the U. S. Department of Agriculture in 1907, and the one direct from the Arnold Arboretum in 1908, included three forms of this species: in the earlier lot under the numbers 19652, 19654, and 19664; in the second lots as *Malus toringo,* yellow fruit, *Malus toringo,* red fruit, and *Malus toringo,* dwarf spreading; of the last the red fruited form was given the number 851, the yellow fruited form the number 853, and the dwarf form became 852. Scions of 19652 and 19654 failed to grow and were thus eliminated. The form under 19664 proved to be dwarf and identical with that under 852. There are then three forms in the collection which may be described.

Malus toringo, red fruit (851)

Represented in the collection by two trees from root-grafts made in January, 1908, three trees from root-grafts of 1914, one tree top-worked on Grimes, and one tree from top-graft on potted Doucin stock. This last tree, forced each spring since 1913, flowered in 1914, again in 1916, and each year since. The top-grafted tree flowered for the first time in 1916, as did also three of the trees from root-grafts of 1908. Trunks of trees from 12 to 18 inches in length, breaking into

several branches all of which are strictly erect. Bark dark reddish-brown, smooth; lenticels conspicuous, rather small, mostly transversely elongated, light grayish-brown; twigs long, slender, purplish-brown, glabrous. All branches have numerous spurs which, on the lower half of the tree, are short, ¼ to 1½ inches long, while above they range from 2 to 3 inches in length. The largest of the older trees is 22 feet 2 inches in height, has a spread of 19 feet 3 inches, and a trunk diameter of 6.2 inches.

Leaves.—Leaves of flowering shoots thin, of delicate texture, and of various forms; lanceolate, elliptical, obovate and spatulate are the more common shapes; 1 to 2 inches long, serrate or sometimes crenate or even entire below and serrate towards the apex, acute, or obtuse, pubescent both sides, glabrate. Leaves of sterile shoots mostly broadly ovate in outline, 3-lobed, occasionally elliptical or obovate, irregularly crenate. The lobed leaves vary considerably in relative size of the lobes; in most the central lobe is much the larger, often indented towards the apex and itself appearing 3-lobed; in other leaves the principal incisions approach the midrib and the lateral lobes are but little smaller than the central; margins are, in part, crenate and, in part, serrate; mostly acute, glabrous thruout when mature, 1¾ to 4 inches in length, 1 to 3 inches broad, somewhat coriaceous. Petioles stout, ¼ to ¾ inch long, usually red as are also the midribs below, glabrous or very nearly so. Stipules foliaceous, ovate, serrate, or variously incised.

Flowers.—This variety flowers from terminal and lateral buds of terminal shoots and from terminal buds of the numerous short spurs. Numbers of flowers to the cluster for 28 clusters examined are as follows: with 2 flowers 1 cluster, with 4 flowers 2, with 5 flowers 5, with 6 flowers 18, and with 7 flowers 2. Young buds deep pink, fading before opening. In fading the margins retain color longest giving the buds, just before opening, a striped appearance. Fully expanded petals are nearly white, some retaining a slight pink tinge along the margins. Flowers expand 20 mm.; pedicels slender, 25 to 35 mm. long, glabrous, as is also the ovary. Calyx lobes narrowly triangular, 3 mm. long, 1 mm. wide at base, acuminate, glabrous without, slightly pubescent within, erect in bud, reflexed but little in open flowers. Petals 5, oval or oblong, rounded at apex, 10 mm. long, 6 mm. wide, claw short. Stamens 12 to 20, distributed, for 76 flowers examined, in numbers as below:

Number of stamens.....	12	13	14	15	16	17	18	19	20
Number of flowers.....	4	5	11	12	13	6	11	5	9

Filaments slender 2 to 5 mm. long, anthers plump, light yellow, pollen orange. Styles 3 to 5; for the 76 flowers there were 32 with 3 styles each, 42 with 4 styles each, and one with 5 styles; slender, 6 mm. long,

connate ⅓ the length, glabrous at base, hairy in a ring above and below the point of separation. Stigmas small, oval, capitate.

Fruit.—Globular, regular at base and apex and in cross-section; sides equal, light or sometimes darker red, usually entirely covering the yellow ground color, no bloom. Skin smooth, thin, tough. Cavity very small, narrow, obtuse, regular; stem rather long, 18 to 25 mm., slender, erect, green, glabrous. Calyx lobes uniformly deciduous early in the development of the fruit. This is one of the smallest fruits represented in the Station collection; the average of 49 fruits weighed and measured is a fruit weighing .33 gram, with a vertical diameter of 7.7 mm. and a transverse diameter of 7.8 mm.; there were 12 fruits with 3 carpels each and 37 with 4 each; they produced 135 seeds, an average of 2.75 to each fruit. Core large in proportion to size of the fruit, cordate, median, closed. Core lines meeting; carpels obovate, glabrous, moderately concave. Seeds small, plump, very light brown. Flesh yellowish, firm, rather dry, acid, and somewhat astringent.

46. *Malus toringo,* yellow fruit (853)

Except for fruit color this is very similar to 851 and may, with propriety, follow that number. Represented by one tree from root-graft of 1908; one from root-graft of 1912; one top-graft of 1912 on Grimes; two trees from root-grafts of 1914, and one tree grafted on potted paradise stock in 1910 and fruited in the house in 1914, again in 1916, and in each year since.

Tree of strictly erect habit; the one tree from root-graft of 1908 and now seventeen years old has a height of 18 feet 7 inches, a spread of 15 feet 2 inches, and a trunk diameter of 5.7 inches. Bark of trunk and large branches dark brown, smooth; twigs reddish-brown, sometimes conspicuously red; lenticels conspicuous, in part round, in part elongated transversely, light gray. Twigs are in general more slender than are those of 851 and short spurs noticeably less numerous. Habit of growth is shown in Fig. 107, which is reproduced from a photograph taken October 26, 1911, of a tree top-worked on Virginia Crab in the spring of 1908. This tree died in 1914 from an attack of blight following removal in 1913 to a new orchard.

Leaves.—Those of flowering twigs of slender form, mainly lanceolate, elliptical or obovate, ½ to 2 inches long, ¼ to ½ inch wide, finely serrate, obtuse or acute, scantily pubescent on both sides. Petioles slender, ½ to 1 inch long, pubescent. Leaves of sterile shoots mostly 3-lobed, sometimes oblong or elliptical, 2 to 4 inches long, ½ to 2 inches broad, serrate, acute, glabrous thruout. Petioles ¾ to 1½ inches long, slender, glabrous.

Flowers.—Produced profusely from terminal and lateral buds of terminal shoots and from short branches or long spurs 3 to 8 inches

long that spring from the larger branches; lateral clusters on these short branches come from short spur-like processes ⅛ to ¼ inch long. Of 15 clusters examined, 5 had 4 buds each, 7 had 5 each, and 3 had 6 each. Buds red or very deep pink, fading to nearly white before petals

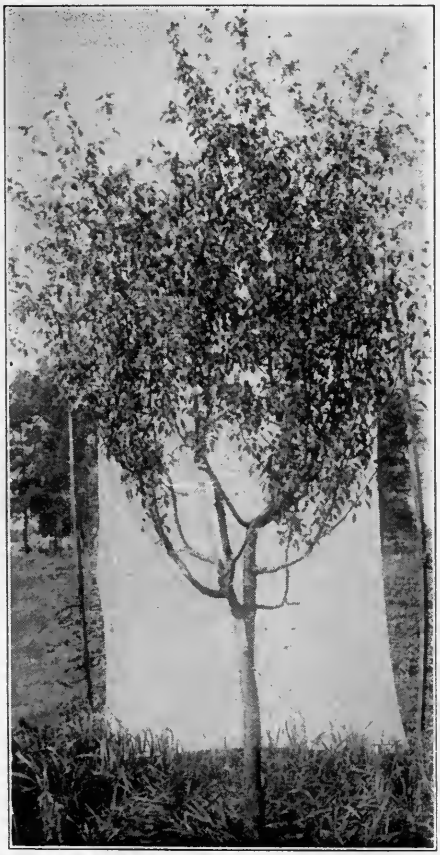

FIG. 107.—TOP-WORKED TREE OF *M. toringo* (853) FOUR YEARS FROM GRAFTS

This species is strictly erect in habit. The tree illustrated here was top-worked on Virginia Crab in the spring of 1908, and was photographed October 26, 1911.

open. Twigs in bud are shown in Fig. 108. Fully open flowers are either pure white or occasionally with a faint tinge of pink; flowers expand 23 mm. Pedicels slender, 21 to 28 mm. long, slightly pubescent as is also the ovary. Calyx lobes 5, triangular acuminate, 3 mm. long,

1 mm. wide at base, glabrous without, slightly pubescent within, erect in bud, reflexed in open flowers. Petals 5, oval or oblong, rounded at apex, 12 mm. long, 8 mm. wide, abruptly contracted at base, claw

FIG. 108.—TWIGS OF *M. toringo* (853) IN BUD IN GREENHOUSE, MARCH 14

Flowering is profuse from terminal and lateral buds of terminal shoots and from short branches 3 to 8 inches long that spring from the larger branches. On these short branches lateral clusters appear on short spur-like processes ⅛ to ¼ inch long.

very short. Stamens for 65 flowers examined vary from 8 to 15 with distribution as below:

Number of stamens	8	9	10	11	12	13	14	15
Number of flowers	1	3	6	24	19	6	4	2

Filaments slender, 5 to 7 mm. long, anthers plump, light yellow. Styles vary from 1 to 4; for the 65 flowers recorded the distribution is as follows:

Number of styles	1	2	3	4
Number of flowers	4	8	33	20

Styles slender, 8 mm. long; connate about ⅕ the length, glabrous at base and above, but hairy about the point of separation. Stigmas small, round, capitate.

Fruit.—Round or sometimes slightly oblate, very small; from 30 fruits weighed and measured the average weight obtained is .21 gram, the average longitudinal diameter 6 mm., and the average transverse diameter 7 mm. The distribution of carpels in these fruits is as follows: 3 fruits had 3 each, 23 fruits had 4 each, and 4 fruits had 5 each. The total number of seeds is 107, an average of 3.56 to each fruit. Fruit regular at base and apex, sides equal, orange-yellow, skin smooth,

FIG. 109.—FRUITING BRANCH OF *M. toringo* (853), OCTOBER 25

Fruits of this species are very small; of 30 fruits weighed and measured the average weight was .21 gram, average longitudinal diameter 6 mm., and the average transverse diameter 7 mm.

thin, tough, dots none; cavity very shallow, sometimes scarcely apparent, narrow, obtuse, regular; stem slender, varying between 13 and 23 mm. in length, glabrous, erect, dull red. Calyx lobes regularly deciduous; basin scarcely apparent. The plane surface of the truncated apex is covered by the circular russet scar left by the deciduous calyx and the only depression is the small, conical calyx tube in the center. Core large in proportion to size of fruit, cordate, oblate, median, half open; carpels obovate, entire, glabrous, deeply concave. Seeds plump, small, very light brown; flesh yellowish, firm, moderately juicy, becoming

rather dry when fully ripe, acid, and somewhat astringent. A fruiting branch of this form is shown in Fig. 109.

47. *Malus toringo* dwarf, spreading (852,19664)

Under the number 19664 this dwarf form of *Malus toringo* is represented by one tree from root-grafts of 1917, one tree top-grafted in 1913, two trees from root-grafts made in 1914, and one tree top-worked on potted paradise for forcing purposes.

FIG. 110.—TOP-GRAFTS OF *M. toringo* (852), SHOWING GROWTH OF FOUR SEASONS

The central vigorous branches belong to the Virginia Crab stock; the grafts are below. The growth of this form of Malus is slow, and the habit of growth is low and wide-spreading with numerous branches contorted in various ways.

Under the number 852 it is represented by three trees root-grafted in 1914. The habit of growth is low and wide-spreading with numerous variously contorted branches. One of the trees from root-graft made in 1907 when ten years old had an extreme height of 6 feet 4 inches, a spread of 9 feet, and a trunk diameter of 3.1 inches. As further illustration of the slow growth of this form of Malus attention may be called to Fig. 110, which shows the growth for four seasons of scions top-grafted in the spring of 1908. The central vigorous branches belong to the Virginia Crab stock; the grafts are below. Bark of trunk gray, the rough outer bark broken into rectangular, scaly plates; bark of branches dark brown; lenticels numerous, small, mostly round, light cinnamon-brown; twigs reddish-brown, stout, glabrous, internodes short.

Leaves.—Those of flowering shoots very small at flowering time and even when mature quite small, elliptical or lanceolate, 1½ to 2½ inches long, ½ to ¾ inch wide, serrate, or irregularly dentate, sometimes irregularly incised, but scarcely lobed, acute,

scantily pubescent on both sides when young, becoming glabrous except along the midrib below. Petioles slender, ½ to 1 inch long, slightly pubescent. Leaves of sterile branches, broadly ovate in outline, mostly 3-lobed, 1¼ to 2½ inches long, ½ to 1½ inches wide, occasionally elliptical, irregularly coarsely dentate or variously incised, acute, commonly folded lengthwise and the midrib curved outward and downward, glabrous above, pubescent below. Petioles short, ¼ to ¾ inch long, stout, pubescent, red, or dark brown; internodes are short and the folded curved leaves appear crowded, particularly near the ends of the shoots.

FIG. 111.—TWIGS OF *M. toringo* (19664) IN BUD IN GREENHOUSE, MARCH 12

Buds are small, globular, and dark red. As they develop, they become elongated and fade to light pink. The open flowers are pure white.

Flowers.—Produced from terminal and lateral buds of shoots and spurs; lateral clusters are either sessile or are raised on very short spur-like processes. Numbers of flowers to the cluster vary between 1 and 7; for 194 clusters examined the distribution is as follows:

Number of flowers to cluster.....	1	2	3	4	5	6	7
Number of clusters.....	2	12	67	73	29	9	2

Buds small, globular, dark red, becoming elongated and fading to light pink. Fig. 111 illustrates a branch (of 19664) in bud as photographed in the greenhouse March 12, 1913. Flowers open pure white, expanding 20 to 23 mm. Pedicels slender, 22 to 25 mm. long, slightly pubescent.

Ovary glabrous, more or less tinged with red. Calyx lobes broadly triangular, obtuse, 3 mm. long, 1½ mm. wide, at base, glabrous without, pubescent within. Petals 5, white, oblong, or obovate, 11 mm. long,

FIG. 112.—FRUITING BRANCH OF *M. toringo* (19664), SEPTEMBER 16
Fruits are round and very small; the average weight of 64 fruits was .25 gram.

7 mm. wide, contracting abruptly to the short claw. Stamens range in number from 7 to 21, as appears from 189 flowers examined:

Number of stamens	7	9	10	11	12	13	14	15	16	17	18	19	20	21
Number of flowers	1	2	1	1	2	4	13	29	34	28	31	13	29	1

Filaments slender, 3 to 6 mm. long, anthers plump, light yellow. Styles slender, 2 to 5. The same flowers examined as to stamens have styles as follows: 1 has 2 styles, 34 have 3 styles each, 136 have 4 styles each, and 18 have 5 styles each. Connate ¼ the length, hairy in a belt about and just above the point of separation, glabrous immediately about the base; stigmas oval oblique extending down the enlarged tips of the styles.

Fruit.—Very small, round; the average of 64 fruits weighed and measured is a fruit weighing .25 gram with a vertical diameter of 6 mm. and a transverse diameter of 7 mm.; regular at base and apex, yellow, sometimes with a slight bronze blush on one side; skin, thin, tough; dots none, cavity none, base rounded to stem as in some pears; stem slender, 22 to 25 mm. long, erect, green, glabrous; calyx lobes regularly deciduous; basin a slightly depressed, circular, russet scar 3 mm. in diameter which has a slight indentation at the center representing the calyx tube. Core large in proportion to size of fruit, obcordate, median, closed; cells mostly 4; of the 64 fruits recorded one had 3 cells, all of the others had 4 each; carpels obovate, entire, deeply concave. Seeds small, plump, light colored. The 64 fruits produced 144 seeds, an average of 2.25 to each fruit. Flesh yellowish, firm, rather dry, acid and astringent. Fig. 112 is a fruiting branch of No. 19664 from photograph made September 16, 1916. A single fruit may also be seen at the extreme right in Fig. 44, page 498.

FIG. 113.—FRUIT OF *Malus* HYSLOP CRAB (824), JULY 23

The ground color of this fruit is clear yellow, entirely overspread with dark red and covered with blue bloom. It is one of the handsomest crabs, and has been cultivated in gardens for many years. Its history is unknown.

M. toringo is an interesting species. Its foliage differs in appearance from that of any other form in the collection; leaves vary remarkably in form; the lobing, the position, and color are distinctive and they exhibit a late autumn change to shades of purple that is seen in few other species. The fruit is more diminutive than any other and is readily distinguished by the truncate apex and the large size of the russet scar. The two tall, erect forms, 851 and 853, have little to separate them except that one has yellow and the other red fruit; there are some slight differences in bark color and in character of spurs, but these may be individual rather than varietal characteristics; in foliage and manner of growth the two are identical and, for breeding purposes, fruit color is the only tangible difference. The dwarf spreading form is distinctly different

from the arborescent forms, not only in habit of growth, but in size, position, and general aspect of leaves. The fruits of both forms are inclined to persist; when subjected to killing frosts they become brown, then gradually shrivel and remain on the trees until spring. The species is native in Japan, and was introduced into Europe and named by Dr. von Siebold in 1856.

48. *Malus* Hyslop Crab (824)

One tree grown from root-grafts made with scions from the Arnold Arboretum in January, 1908, is vigorous, erect, and because of spreading lower branches distinctly pyramidal in form and perfectly symmetrical; height 20 feet 6 inches, spread 21 feet 7 inches, trunk diameter 8.8 inches. The bark of trunk is dark greenish-brown, branches somewhat lighter; twigs pubescent, reddish-brown.

Leaves.—Three to 4 inches long, 1¼ to 2 inches wide, ovate, oblong, or elliptical; acute or acuminate, irregularly coarsely serrate; pubescent below when young, becoming nearly glabrous; above, dark green, glabrous, petioles stout, slightly pubescent, ¾ to 1½ inches long.

Flowers.—Flowering from terminal and lateral buds of shoots and spurs, 4 to 7 buds in each cluster. Pedicels 1 inch in length, pubescent, moderately stout; calyx lobes long-acuminate, 8 mm. long, pubescent both sides. Petals in bud light pink, becoming white in open flowers; rounded ovate with very short claw. Flowers expand 32 mm.; stamens about 20, filaments slender, 6 to 8 mm. long, anthers plump, lemon yellow; styles 5, longer than the filaments, hairy at base, stigmas oval, oblique.

Fruit.—Round or somewhat oblong, or sometimes slightly oblate. Weight as averaged from 100 fruits 42.44 grams; longitudinal diameter 38 mm., transverse diameter 44 mm. The ground color is clear yellow entirely overspread with dark red and covered with blue bloom. The skin is smooth, tough, and rather thick; dots many, small, round, pale, conspicuous; cavity moderately deep, acuminate, regular; stem medium to long, 18 to 30 mm., slender, erect, glabrous; basin shallow, broad, irregular; calyx rather large, closed; lobes long, slender, acuminate, reflexed. Calyx tube conical, stamens marginal. Core of medium size, cordate, elliptical, median, closed; carpels regularly 5, obovate, glabrous, slightly concave; seeds small, dark, averaging 6.75 to each fruit. Flesh yellowish, firm, acid, becoming subacid, dry, and mealy when over-ripe. This is one of the handsomest crabs, its history is unknown, but it has been cultivated in gardens for many years. Fig. 113 is from photograph of a single fruit, natural size, as it hung on the branch; another fruit, also natural size, may be seen between and in contrast with fruits of *M. soulardi* and *M. sylvestris fl. pl.* in Fig. 98, page 571.

49. *Malus* Yellow Siberian Crab (857)

Scions received from the Arnold Arboretum January, 1908. The variety is in the collection as No. 857 and is at the present time represented as follows: one tree from root-graft of January 20, 1908, now sixteen years old, 16 feet high, with spread of 16 feet 9 inches and trunk diameter of 5.3 inches; has flowered each year since 1912; one tree root-grafted January 12, 1914; one tree top-worked March 17, 1911, on Virginia Crab; one tree top-worked on Wolf River; and one tree top-grafted on potted paradise stock for forcing purposes; this dwarf was grafted February 23, 1910, and has flowered in the greenhouse each year since 1913. Trees of this variety are all of erect habit, but become more and more wide-spreading as they get older. The variety is very susceptible to attacks of the blight disease and some of the trees have been severely pruned in removing diseased branches. Bark smooth, grayish-brown with a yellowish tinge; twigs light reddish-brown.

Leaves.—Oval, ovate or oblong, 2 to 3½ inches long, some smaller leaves nearly orbicular, rounded at base, shortly acute at apex, crenate-dentate, pubescent when young, becoming glabrous thruout in age; petioles ½ to 1¼ inches long, slender, pubescent.

Flowers.—Produced from terminal and lateral buds of terminal shoots and from terminal buds of short spurs. Number of buds to the cluster for 108 clusters examined is as follows; with 3 buds, 1; with 4 buds, 14; with 5 buds, 35; with 7 buds, 13; with 8 buds, 2; and with 11 buds, 5. Buds globular, becoming oblong, obtusely rounded, greenish-white; open flowers pure white, expanding 32 mm. Pedicels 15 to 20 mm. long, stout, pubescent; calyx lobes 5, linear, acuminate, pubescent both sides; petals ovate, emarginate, claw short, length 15 mm., breadth 11 mm. Stamens vary from 10 to 20, filaments slender, 4 to 8 mm. long; anthers plump, light yellow. Styles 5, slender, 8 mm. long, distinct nearly to the base, glabrous; stigmas small, oval, oblique. Ovary densely white tomentose.

Fruit.—Round or sometimes slightly oblate, more or less irregular both at base and apex, cross-section obscurely ribbed and sides commonly slightly unequal; weight, averaged from 288 fruits, is 17.6 grams, longitudinal diameter 28 mm., transverse diameter 33 mm. Yellow with occasionally a faint pink blush on one side; a waxy white bloom is evident but not abundant; skin smooth, thin, tender; dots few, small, round, gray, inconspicuous. Cavity of medium depth, broad, obtuse, regular; stem rather long, commonly 30 mm., slender, clavate, erect, green, pubescent; calyx of medium size, pubescent, closed. Basin shallow, broad, obtuse, more or less ribbed; calyx lobes long, slender, reflexed; usually persistent, but sometimes deciduous in the same manner as in forms of *M. baccata.* Of 228 fruits exam-

ined, 264 or 91.66 percent retained the calyx lobes while 24 or 8.34 percent had deciduous lobes. Calyx tube rather short, small, conical; core of medium size, cordate, median, closed; stamens median, core lines clasping; carpels obovate, entire, moderately concave. Seeds plump, of medium size, dark brown. Seed production as averaged for 288 fruits is 6.98. This is a high average; of 25 species and varieties of the crab-like forms only one has a higher average. Flesh yellowish, firm, crisp, rather dry, acid. At the left of Fig. 45, page 503, is a single fruit of this crab, photographed in company with a fruit of *M. sylvestris fastigiata bifera* (center) and one of *M. ioensis* (right) for ready comparison of general appearance, all natural size.

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